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Dual-Task Effects of Walking on Rate of Speech

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Health and Rehabilitation Sciences

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DUAL-TASK EFFECTS OF WALKING ON RATE OF SPEECH

(Thesis format: Monograph)

by

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Graduate Program in Health and Rehabilitation Science

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

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Abstract

The dual-task effect of walking on rate of speech was measured in 32 healthy young adults. The influence of word meaning and sex on rate of speech was also investigated. A separate inspection time task was used to determine whether speed of information processing (SIP), predicted the degree of dual-task interference of walking on rate of speech. This study revealed that rate of speech was influenced by dual-task interference effects due to the performance of a simultaneous gait task. Pause times suggested a sex effect, demonstrating that while walking, women spent significantly less time pausing between verbal stimuli than men. Articulation rates suggested a lexical effect, demonstrating an increase in dual-task interference when participants repeated real-words rather than non-words while walking. Results revealed that SIP did not predict the degree of dual-task interference on rate of speech. This study adds to our understanding of the dual-task effects of walking on rate of speech in healthy, young adults.

Keywords: Rate of speech, dual-task interference, processing capacity, lexicality, sex differences

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Chapter 1

1 Introduction

1.1 Research Regarding Dual-Task Paradigms, Walking, and Speaking

Dual-tasking is defined as the ability to perform two tasks simultaneously. Studies have shown that people have difficulty completing two tasks at the same time (Pashler, 1994; Huang & Mercer, 2001). In one line of research, dual-task paradigms have been used to study the influence of speech on gait. Armieri, Holmes, Spaulding, Jenkins, and Johnson (2008) examined dual-task interference on gait using a digit memory task. Each of the 14 healthy, young participants tested was assigned a randomized number to remember. Participants were asked to rehearse that number while walking along a 23’ instrumented carpet (a GAITRite mat). The researchers crossed task complexity and articulation within the verbal memory task; task complexity was varied by the number of digits a participant had to memorize (e.g., 3 digits, 5 digits, 7 digits, or baseline; no memory task) and articulation was varied by rehearsal type (e.g., silent or out loud). The results of this study revealed that the effects of dual-task interference were greater when individuals had to speak more complex digit strings out loud (Armieri et al., 2008). However, these researchers did not manipulate the cognitive-linguistic complexity of the verbal stimuli. Without this manipulation, it could not be determined whether the evidence of dual-task interference was due to the motor-speech or linguistic demands of the digit strings.

Stemming from the work of Armieri et al. (2008), Davie, Oram Cardy, Holmes, Gagnon, Hyde, Jenkins, and Johnson (2011) systematically manipulated word length, oral–motor movement, articulatory, and lexical demands of speech stimuli within a secondary verbal task to determine dual-task effects on gait. They crossed two word lengths (monosyllabic vs. bisyllabic) and four conditions of task complexity (no dual-task, non-speech movement, spoken real-word, and spoken non-word) during a continuous gait task. The results of this study revealed that oral-motor demands produced the greatest effect of dual-task interference on gait.

The aforementioned studies have opened many avenues of research regarding speech, gait and dual-task paradigms. The research of Armieri et al. (2008) and Davie et al. (2011) offers evidence that articulatory demands are an important predictor of dual-task interference on gait; however, little research exists on the impact of gait on speech.

1.2 Dual-Task Interference

It is important to understand the underlying mechanisms of dual-task performance because these mechanisms can help us to better understand an individual's overall ability to function (e.g., process tasks). There is often an assumption that multi-tasking is beneficial. However, dual-tasks such as driving and talking on a cell phone, driving and texting, or walking and texting can present collateral effects that include, but are not limited to, overlooking key instructions, inhibiting clear thought processes, disregarding important environmental events (i.e., traffic or pedestrians), or risking the safety of self or others (Pashler, 1994). By investigating dual-task interference, we can begin to discover how individuals process information simultaneously and apply this understanding to practical problems of multitasking in daily living.

1.3 Dual-Task Theories

Past research has suggested that dual-task interference can occur if tasks are considered physically incompatible or intellectually challenging (Pashler, 1994). However, more recent studies have shown that it is common for individuals to experience difficulty completing two concurrent tasks, regardless of these considerations (Huang & Mercer, 2001; Armieri et al., 2008).

Theoretical accounts of dual-task interference are diverse and remain widely debated within the dual-task literature. Some theories have received much attention, including the bottleneck (task switching) model (Pashler, 1984; McCann & Johnston, 1992; Pashler, 1994), cross talk model (Navon & Miller 1987; Pashler, 1994) and functional distance hypothesis (LaBarba, Bowers, Kingsberg, & Freeman, 1987; Dromey & Shim, 2008).One of the most generally accepted hypotheses to date, however, is the capacity sharing model (Pashler, 1994; Huang & Mercer, 2001).

Bottleneck (task-switching) model. The bottleneck theory states that the effects of dual-task interference are based upon the type of stimuli that are being processed, rather than the individual's system capacity (Pashler, 1994). According to this model, dual-task interference occurs because the processing system can only allocate attention to one task at a time. For example, some mental operations require the independent use of a processing system. When two stimuli require the same processing system, they are forced to compete in order to be processed. In this circumstance, a subsequent bottleneck response will occur, causing the response selection in one or both tasks to become impaired or delayed (Pashler, 1984; McCann & Johnston, 1992). Single and multiple bottlenecks can occur at different stages of central processing or within different types of operations. This theory has been tested using paradigms tapping the psychological refractory period (PRP). The PRP is a delay period that occurs when a processing system must respond to two tasks that are presented in close sequence. This delay typically increases when the time between task presentations decreases (Pashler, 1994).

Cross-talk model. Similar to the bottleneck theory, the cross talk model considers the type of task that is processed, but suggests that dual-task interference occurs because one task produces side–effects that hinders the processing of the other task. Therefore, dual-task effects are driven solely by the content of the stimuli (Pashler, 1994). Stimulus content might include what the individual is thinking, what sensory inputs are present, or what responses are produced during information processing. In principle, this model assumes that a neuronal advantage exists during dual-tasking. For instance, two tasks requiring the same processing resource would use the same neurons and facilitate ease of simultaneous production. However, some theorists argue the opposite, believing that it is more difficult to complete two concurrent tasks when they are similar. Navon and Miller (1987) suggest that dual-task interference is a result of "output conflict", a situation in which the processing of one task generates throughputs, outputs, or side-effects that hinder the processing of the other task. If cross talk is the source of difficulty in dual-task production, one should therefore find that interference decreases when two tasks are sufficiently different. Unfortunately, there is limited evidence supporting this theory.

Functional Distance Hypothesis. LaBarba et al. (1987) investigated the functional distance hypothesis, which suggests that dual-task interference is greater when two concurrent tasks are anatomically closer (i.e., require the use of the same hemisphere for processing). Therefore, tasks regulated by brain networks that are proximal will interfere more with each other than tasks that are controlled by spatially distant regions. LaBarba et al. (1987) hypothesized that an individual who was tapping their finger while speaking would expectedly experience more effects of dual-task interference than an individual who was tapping their foot while speaking. This theory differs from the previously mentioned theories because it incorporates the regions of the brain utilized during processing, as well as the type of tasks that are processed. However, LaBarba et al. (1987) did not find significant evidence to support this theory despite the different functions and anatomical location of motor centers from the speech centers. In 2008, Dromey and Shim re-examined the functional distance hypothesis. In their study, twenty young adult participants were asked to complete a verbal fluency task (i.e., listing words that begin with the same letter), a speech task (i.e., repeating a sentence) and left and right-handed motor tasks (i.e., placing pegs in a pegboard) (Dromey & Shim, 2008). All tasks were completed in isolation and concurrently; however, the results of this study did not show sufficient support for the functional distance hypothesis. Based on the results of LaBarba et al. (1987) and Dromey and Shim (2008) an individual’s ability to dual-task may be more complex than is predicted by this hypothesis.

Capacity sharing model. The capacity sharing model is of particular relevance to the proposed study. This model is based on the assumption that humans have a finite mental capacity that is shared among tasks. Due to this shared capacity, individuals may be able to multi-task; however, they will experience dual -task interference because their attention is divided between two subsequent tasks (Pashler, 1994; Huang & Mercer, 2001). This model makes two main assumptions. First, individuals allocate their attention to tasks that are more difficult. Therefore, if a primary task requires larger amounts of processing capacity, it is expected that the performance of a secondary task will be weakened. Second, the amount of available processing capacity decreases each time an individual undertakes an additional task. In such circumstances, an individual may sacrifice performance on a primary task in order to complete a secondary task. Based on these assumptions, the capacity sharing model states that parallel processing will result in dual-task effects on the performance of one or both tasks (Pashler, 1994; Huang & Mercer, 2001).

1.4 The Relationship between Speed of Information Processing and Dual-task Theory

Speed of information processing is the rate at which an individual detects and responds to stimuli (Sheppard & Vernon, 2008). Both inspection time and reaction time have been used as chronometric assessments of information processing capacity. The exposure period of a stimulus is limited within an inspection time task. Therefore, inspection time measures the period of exposure required for a participant to correctly identify properties of a given stimulus (Nettelbeck, 1982).

Inspection time offers a measure of information processing capacity because it is not threatened by confounding motoric speed (Sheppard & Vernon, 2008; Nettelbeck, Edwards, & Vreugdenhil, 1986). For example, a reaction time task measures the speed at which an individual responds to a stimulus (i.e., the amount of time it takes to press a button in response to a beep). In this circumstance, there is a possibility that the participant's cognitive speed may become confounded by motoric speed (i.e., a participant may be quick to cognitively process information, yet slow to push a button in response). Inspection time is a simple and efficient method of measurement that has been linked to aspects of intellectual ability (Deary & Stough, 1996; Brody, 2001). Therefore, inspection time may estimate for capacity of individual cognitive systems within a dual-task paradigm. An information-processing speed task, applied separately from dual-tasks, can be used to directly assess the capacity sharing model, and, potentially, to predict individual differences in dual-task interference.

1.5 Rate of Speech

Overall/Total speech rate. According to Hall and Yairi (1997), speech rate, or total speech rate as it is referred to in this study, reflects the integrity of a speaker's speech motor control system. It can be defined as the speed at which speakers shape and configure their oral cavities to perform articulatory movements necessary for speech production (Crystal & House, 1982; Pellowski, 2010).

Rate of speech is commonly calculated as the number of output units produced within a given unit of time (Goldman-Eisler, 1956, 1961; Tsao & Weismer, 1997). This time interval includes the duration of pauses and halts that break up a continuous flow of verbal output (Goldman-Eisler, 1956). Speech rate is most commonly measured in a syllable per second timeframe (Logan, Roberts, Pretto, & Morey, 2002; Goldman-Eisler 1956, 1961*)*. Units of measurement, such as words per minute or phonemes per minute, can also be used to analyze speech rate (Carroll, 1967). However, these units of speech measurement can be criticized for two main reasons. First, speech samples vary in their average word length, making words per minute a non-standardized unit of measurement. In contrast, a syllable is a more practical unit to measure because its variability from text to text is still less than the average variability in word length (Carroll, 1967). Second, phonemes are often discounted in speech measurement since phonemes are difficult to count. Overall, words vary in syllabic length, but syllables can be easily distinguished and standardized amongst texts, which makes the basic unit of a syllable a more precise and favorable estimate of speech rate (Carroll, 1967).

Components of total speech rate. Researchers suggest that an individual's rate of speech should be interpreted as two separate components including, articulation rate and pause time (Nishio & Niimi, 2000; Flipsen 2002, 2003).

***Articulation rate*.** Articulation rate is defined as the number of output units (syllables) produced within a given unit of time following the removal of silent intervals such as halts and pauses (Goldman-Eisler, 1956; Robb, Gilbert, Reed, & Bisson, 2003). Exclusion of silent intervals focuses measurement on the duration of articulatory runs (Tsao & Weismer, 1997). An articulatory run is the speech produced between two consecutive pauses. The overall mean articulation rate, or “true speech”, of an utterance can be calculated by averaging the number of syllables produced per articulatory run (Grosjean & Collins, 1979; Tsao & Weismer, 1997).

Pause time. Pause time is the accumulation of pause duration over a given unit of time (Nishio and Niimi, 2001). An individual pause is defined as the duration of time that exists from the offset of one articulatory run to the onset of the next articulatory run (Tsao & Weismer, 1997). Goldman-Eisler, 1968 describes a pause as a period of time (typically equal or greater to 250 milliseconds), in which no phonation is made. Similarly, Grosjean & Collins (1979) describe a pause as a disruption of verbal output that lasts more than 200 milliseconds (msec). However, a criterion of 200 msec or more is often criticized for its lack of clarity (Tsao & Weismer, 1997). For example, the literature states that a typical stop closure interval lasts anywhere from 70 to 100 msec (Stathopolous & Weismer, 1983). Based on this finding, Tsao and Weismer (1997) suggest that a decrease in time criterion is required to clarify boundaries between a stop closure interval and a pause. Tsao and Weismer (1997) proposed that a pause should be identified as an interruption of a sound wave that lasts at least 150 msec or more. They also argued that a criterion of 200 msec is too broad; asserting that lowering a pause criterion to 150 msec decreases the likelihood of excluding relatively short pauses that may occur when a speaker reads at a faster rate. This is particularly important when analyzing normal populations whose speech rates can vary considerably (Tsao & Weismer, 1997).

Many researchers (Pellowski, 2010; Grosjean & Collins, 1979; Walker & Archibald, 2006) argue that articulation rate (e.g., number of syllables produced per second, excluding pauses) is a more accurate measurement of speech rate (e.g., speed at which speakers shape and configure their oral cavities to produce speech (Crystal & House, 1982; Pellowski, 2010)). Both articulation rate and pause time contribute to total speech rate, but the variability of pause time can manipulate total speech rate measurement. For instance, pause time may fluctuate due to a wide variety of circumstances and factors, including the individual speaker, the speaker's emotional state, and the situation in which the speaker is speaking (Robb et al., 2003). Any fluctuations in pause, such as an increase in frequency or duration, will cause a corresponding change to total speech rate. Therefore, increased pause times can cause total speech rate to appear slower (Walker & Archibald, 2006). A substantial amount of literature agrees that articulation rate, excluding pause time, provides a more representative and sensitive estimate of speech rate in a given speech sample (Grosjean & Collins, 1979; Tsao & Weismer, 1997; Walker & Archibald, 2006).

Despite these viewpoints, the clinical measurement of speech rate typically measures overall rate and all of its components. For instance, Nishio and Niimi (2001) studied the relationship between speech rate and its components in dysarthric speakers. The aforementioned calculations of speech rate, articulation rate and pause time were employed in this study. A speech/pause ratio was also used. This ratio was derived by "dividing the pause time by the duration of the total speech sample, including both articulation time and pause time (Nishio & Niimi, 2001: p.311)". Results of this study showed no significant relationship between total speech rate and articulation rate; therefore, these researchers argued that values of articulation rate and speech/pause ratios should both be included in the clinical measurement of rate of speech (Nishio & Niimi, 2001). Overall, it is important to recognize the ways in which speech rate can be measured, and understand that the incorporation of both speech rate components (articulation rate and pause time) is essential within the clinical measurement of rate of speech because each variable individually contributes to an overall measure of total rate of speech.

Average rate of speech for healthy young adults. Knowing typical values for average speech rate production is important when establishing appropriate guidelines for rate control therapies (Venkatagiri, 1999), especially when those therapies are employed by individuals with motor speech problems and associated alterations in speech rate (e.g., individuals with Parkinson's disease, Multiple Sclerosis). Previous literature indicates that adult speakers of American English (AE) typically have an overall/total speech rate (pauses included) of approximately 250 syllables per minute (SPM) and an articulation rate of approximately 300 SPM (e.g., Robb & Gillon, 2007; Crystal & House, 1990; Kowal, O'Connell, & Sabin, 1975). A study conducted by Venkatagiri (1999) investigated discourse (connected speech) rates and utterance rates in a group of healthy young adults. Results from this study report that a mean speaking rate, for healthy adults, is roughly 143 words per minute (WPM) or 195 syllables per minute (SPM) while talking, and 147 WPM (187 SPM) when describing a picture in a spontaneous speech task. Venkatagiri (1999) noted that rates of reading and conversational speech were comparable, whether measured in syllables per minute or words per minute, in both men and women's speech. These results are similar to those of Lutz and Mallard (1986) who suggest a mean conversational speech rate of 159 WPM (217 SPM), and Duchin and Mysak (1987) who demonstrated that young adults described pictures at a mean rate of 151 WPM (202 SPM) and conversed at a mean rate of 183 WPM (236 SPM).

Clinical populations who benefit from rate of speech analyses and intervention. The assessment of rate of speech can play an important role in the diagnosis, evaluation and treatment of clinical populations. For example, the measurement of rate of speech is a useful clinical outcome measure in the dysarthrias. Dysarthria is a "collective name for a group of speech disorders resulting from disturbances in muscular control over the speech mechanism due to damage of the central or peripheral nervous systems" (Darley, Aronson & Brown 1969, p. 246). Dysarthria is often associated with chronic neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS) that results in mixed dysarthria, Parkinson's disease (PD) that leads to hypokinetic dysarthria or Friedreich's ataxia that can result in ataxic dysarthria. Darley and his colleagues identified five dysarthria types (flaccid, spastic, ataxic, hypokinetic, and hyperkinetic) based on clusters of salient perceptual speech features associated with lesions in the central and peripheral nervous systems unique to each dysarthria type. Regardless of the underlying neuromotor impairment and the heterogeneity of each of the dysarthrias, speech rate production is commonly affected. For example, all dysarthria types are associated with a reduction in speaking rate with the exception of hypokinetic dysarthria which can be associated with an increase in speaking rate (Duffy, 2005). In 2000, Nishio and Niimi compared the speech samples of 2 participants with early stage ALS to control participants. The results of this study revealed that speakers with ALS displayed considerably slower speech rates than control participants, but the participants with ALS were able to maintain relatively high speech intelligibility levels early on in the disease process. This study suggests that measuring speech rate in this clinical population can be a more sensitive parameter than measuring overall speech intelligibility for detecting abnormal speech production in early stage ALS (Nishio & Niimi, 2000).

The following year, Nishio and Niimi (2001) conducted a study of persons with a variety of dysarthria types. Results of this study demonstrated that a significant decrease in speech rate was evident for all types of dysarthria studied, including hypokinetic, ataxic, spastic, flaccid, mixed and unilateral upper motor neuron types. Evidence from both (Nishio & Niimi, 2000; 2001) studies confirms that speech rate is a sensitive parameter that is useful in determining abnormal motor speech production in individuals with dysarthria.

Factors Influencing Rate of Speech. Several factors can influence an individual's rate of speech. Within-speaker factors are generally inherent features of speech that, in combination, create an individual's unique speech characteristics. Within-speaker factors include an individual's habitual speech rate, their use of voice and prosody, the length of the utterance, their mood, and the speaking situation (e.g., noisy environment versus a quiet environment) (Jacewicz, Fox, O'Neill & Salmon, 2009). In comparison, between-speaker factors are related to social variables such as age, gender, education, socioeconomic status, occupation or geographic origin (Jacewicz et al., 2009). A large proportion of the literature on rate of speech has focused on the examination of the variability of speech rate due to type of task or stimuli administered (Crystal & House, 1982; Goldman-Eisler, 1961) or the length of the utterance that is spoken (Fonagy & Magdics, 1960; Haselager, Slis, & Rietveld, 1991; Robb et al., 2003). Other research has focused on speaker variables, focusing analyses on the potential effects of age or gender. The literature that has investigated the potential effects of these within-speaker and between-speaker factors is quite broad; however, relevant findings from a select few papers will be discussed below.

Type of Task or Stimuli. Rate of speech can be influenced by the type of task or stimuli. For example, Crystal and House (1982) analyzed and compared speech rate produced during a conversational task versus a reading task. Results from this study revealed that rate of speech increased during the production of a conversational speech task and slowed in a formal production task (i.e., reading). Other circumstances, such as spontaneous versus practiced speech have also been shown to display differences in rate of speech based on task. Goldman-Eisler (1961) found that extra time offered to practice speech allows a speaker to improve proficiency on a given speech task. For example, this study demonstrated that practiced speech is produced at a faster rate than spontaneous speech (Goldman-Eisler, 1961).

Utterance Length. Many studies have analyzed the impact of utterance length on speech rate (Fonagy & Magdics, 1960; Haselager et al., 1991; Walker, Archibald, Cherniak, & Fish, 1992; Robb et al., 2003). In general, the literature suggests that the relationship observed between these two variables is different for adult and child populations (Robb et al., 2003). Adults tend to speak at a faster rate if utterances are long and at a slower rate if utterances are short (Haselager et al., 1991; Fonagy & Magdics, 1960; Robb et al., 2003).This finding indicates that utterance length has a strong impact on speech rate in adults. In contrast, it appears that utterance length does not alter a child's rate of speech. For example, no significant relationship was found between utterance length and speech rate in children aged 3-5 (Walker et al., 1992). It is theorized that children are still learning speech motor control mechanisms; making age differences a plausible explanation for the observed differential patterns of speech rate associated with utterance length within these two populations (Walker et al., 1992).

Age. Unfortunately, the effect of age is not clearly outlined in the speech rate literature. Most commonly, research shows that an adult's overall speech rate is faster than a child's (Robb et al., 2003; Kowal et al., 1975). This demonstrates a progressive pattern of increasing speech rate that is analogous to increases in chronological age (Robb et al, 2003; Chermak &

Schneiderman, 1985; Kowal et al., 1975). This research supports that of Walker et al., (1992) which suggests that rate of speech increases from childhood to adulthood.

In 1983, Ramig measured and compared the speech rates of adults who differed in age (25-35 years; 45-55 years; 65-75 years) and physical condition ("good" vs. "bad"). Physical condition was based upon measures of resting heart rate, diastolic and resting systolic blood pressure, vital capacity and body fat percentages. Results from this study demonstrated that as participant age increased, the rate of speech across participants decreased in both spontaneous (conversational) speech tasks and reading speech tasks (Ramig, 1983). Ramig did not specify speed of information processing as a contributing factor to differential speech rates; however, the measured physical conditions, along with other physiological factors such as vision and neuromuscular impairments, were all cited as plausible age-related explanations for speech rate differences (Ramig, 1983, p.8). An age-related decline in speech rate was also evident in Verhoeven, De Pauws & Kloots' 2004 study. This study suggests that older adults typically speak slower than young adults during conversational speech tasks (Verhoeven et al., 2004). As an explanation of this finding, Jacewicz et al. (2009), also referenced past research (Haselager et al., 1991; Fonagy & Magdics, 1960; Robb et al., 2003; Quené, 2008) and suggested that this age-related difference may be due to trends in utterance length. For instance, young adult speakers tend to produce relatively longer phrases than older adults (Quené, 2008). Quené (2008) explained that longer sentences possess more syllables and therefore, tend to be spoken at a faster rate, causing syllable duration to shorten and overall speech rate to increase. Given this evidence, Quené (2008) theorized that older adults tend to produce shorter sentences, at slower speech rates because they contain fewer syllables. Therefore, the impact of utterance length on speech rate may account for age-related differences between young and old adults (Quené, 2008).

Gender. The effects of gender are of particular relevance to the proposed study. Currently, there are conflicting results of the effect of gender on speech rate. Some studies such as one by Venkatagiri (1999), showed no difference in speech rate between men and women while reading aloud or speaking, while other studies have found gender effects (Lutz & Mallard, 1986; Jacewicz et al., 2009; Verhoeven et al., 2004). For example, Lutz and Mallard (1986) recorded and compared men and women's rate of speech, while reading a standard passage aloud. Lutz and Mallard's results suggested that men read faster than women (however, no statistical analyses were performed on these results). More recent studies have also found men to speak faster than women when completing reading tasks (Jacewicz et al., 2009) and conversational tasks (Verhoeven et al., 2004). It is noted, however, that the statistical significance of data used to cite these findings is often weak. For example, Jacewicz et al. (2009) made mention that the results of their study should be interpreted with caution, citing weak data. Therefore, their study suggests that males speak faster than females, specifically, when they are observed in formal circumstances such as reading. Due to the diversity and conflicting nature of the research literature the relationship between gender and speech rate remains uncertain.

Individual factors. The individual, idiosyncratic nature of speech rate observed in normal adults has also been examined. In order to account for individual variation in speech rate, Tsao and Weismer (1997) tested two hypotheses: a neurological hypothesis and a sociolinguistic hypothesis. The premise of the neurological hypothesis is that neurological predispositions are proposed to determine habitual (conversational) speaking rates. By contrast, the sociolinguistic hypothesis proposes that speakers consciously choose to speak at a speech rate that is representative of their personality. For instance, a shy or a professional individual might choose to speak slower, while someone who is ambitious or intelligent may consciously choose to speak faster (Tsao & Weismer, 1997; Ray, 1986).

In the Tsao and Weismer (1997) study, participants were asked to read a speech sample at a habitual speech rate and at a maximum speech rate to determine whether individuals with a slow habitual speech rate have the same upper limit as speakers with a habitually fast rate. Results were most consistent with the neuromuscular hypothesis. Overall, slow speakers demonstrated a significantly slower maximum articulation rate, supporting the proposal that neuromuscular characteristics likely constrain an individual's maximum speech rate. Despite these results, it should be noted that Tsao and Weismer did not suggest that the neuromuscular hypothesis is solely accountable for the variance observed in individual speech rates.

Motor Entrainment. Motor entrainment should be considered a potential factor that may influence one's rate of speech, especially while dual-tasking. Motor entrainment can be defined as muscle movements that are controlled by coordinative structures and performed in oscillation; when two oscillations have a consistent phase relationship and occur in the same frequency, they are said to be "entrained" (Smith, McFarland, & Weber, 1986). This factor is of particular interest in the present study. Previous research has investigated the use of auditory rhythm as a sensory stimulus in the facilitation of gait patterns and in patients with a variety of movement disorders. For instance, McIntosh, Brown, Rice and Thaut (1997) analyzed the effect of rhythmic auditory stimulation (RAS) in a Parkinsonian population and found that auditory stimulation, especially when provided at a faster speed, produced improvements in the mean gait velocity, stride length, and cadence of individuals with Parkinson's disease. This study investigated 31 individuals with Parkinson's disease, 10 of whom received medication (ON group) and 21 of whom received no medication (OFF group). During this study, participants walked in four different conditions, two of which incorporated the use of a rhythmic auditory stimulus (e.g., Baseline RAS and10% faster than baseline). Results from this study suggest that despite dysfunction of the basal ganglia, individuals with Parkinson's disease (both in the ON and OFF group) showed a strong synchronization between step frequency and rhythmic entrainment (McIntosh et al., 1997). Of interest to the current study, is the work of Bernardis & Gentilucci (2006) who investigated the interaction of speech production and symbolic gesture. In this study, participants were asked to gesture and pronounce words separately, and then asked to complete the same tasks simultaneously. These tasks enabled researchers to examine whether communication signals influenced each other when sent simultaneously. The results of this study found that gestures reinforced and enhanced speech production, whereas words reduced and inhibited gesture production; however the level of interference was dependent upon the level of execution and processing (Bernardis & Gentilucci, 2006). Despite these studies, there appears to be limited published research that has investigated the synchronization of motor speech production and gait patterns.

1.6 Dual- Task Effects on Speech and Language

There have been few studies that have investigated the influence of linguistic demands on speech production, especially within a dual-task paradigm. However, researchers such as Dromey and Bates (2005) have argued that an understanding of linguistic demands and speech production is vital in order to fully understand language formation and speech motor activity. Their study found that speech motor activity could influence, and be influenced by, linguistics demands. This finding supports the results of previous studies (e.g., Smith et al., 1986; LaBarba et. al, 1987). For instance, Smith, McFarland and Weber (1986) asked their participants to repeat one syllable words while tapping a finger. Results from this study found that the motor movement of tapping and the speech production of words both influenced one another in the rate and magnitude of participant's speech. The following year, LaBarba et al. (1987) examined the functional distance hypothesis. Results from this study did not provide evidence to support the functional distance hypothesis; however, results demonstrated significant tradeoff effects between dual-task conditions, including evidence that individuals typically increase their rate of speech while tapping a finger simultaneously. Results from these investigations suggest that mutual influences exist between manual motor activity and speech movements and may potentially relate to the influence of motor entrainment.

1.7 Rationale

Numerous researchers have investigated the influence of speech on gait within a dual-task paradigm. The literature on gait and speech production suggests that articulatory demands are an important predictor of dual-task interference on gait; however, little research exists on the impact of gait on speech production. Furthermore, there is a paucity of literature that has addressed speed of information processing, and the particular influence that one's processing speed may have on one's speech performance (e.g., rate of speech) within a dual-task paradigm. The purpose of this study is to examine the dual –task interference that walking may confer on one's rate of speech. Several variables that could contribute to dual-task interference on walking will be considered, including, word meaning and sex. In addition, an analysis of speed of information processing will be used in collaboration with this study to determine whether an individual's processing speed can predict the degree of dual-task interference of walking on rate of speech. The presence of dual-task interference in a healthy population may have significant implications for at risk populations (e.g., individuals with Multiple Sclerosis or Parkinson's disease) since individuals with these diseases may experience intensified effects of dual-task interference due to motor impairments, including motor speech impairments characteristic of these diseases (Davie et al., 2011). Defining relationships among these variables will add to a small empirical literature examining the effect of gait on rate of speech and speed of information processing. In addition, with continued study, this line of research may have important future implications for the functional assessment and treatment of individuals with motor disorders such as MS or PD.

Four objectives were examined in this study. These objectives are:

1. To examine the dual-task interference effects of walking versus standing on total rate of speech and rate of speech components (i.e., articulation rate, pause time) during the production of real-words and non-words.
2. To examine the influence of word meaning and sex on speech frequency measures (e.g., total speech rate, articulation rate and pause rate) during the production of real-words and non-words within a dual-task paradigm.
3. To examine the influence of word meaning and sex on speech duration measures (e.g., total speech time, articulation time and pause time) during the production of real-words and non-words within a dual-task paradigm.
4. To examine the extent to which dual-task effects of walking on rate of speech were due to speed of information processing.

1.8 Research Questions

The extant literature on walking and speech production has suggested that articulatory demands are an important predictor of dual-task interference on gait. Unfortunately, the influence of walking on rate of speech has received little attention in the literature to date. The following specific research questions will be examined in the present study:

1. Does walking interfere with total rate of speech and its individual components (e.g., pause time and articulation rate)?
2. Is dual-task interference of walking on rate of speech influenced by word meaning?
3. Is dual-task interference of walking on rate of speech influenced by sex?
4. Does individual speed of information processing predict degree of dual-task interference of walking on rate of speech?

Chapter 2

2 Method

2.1 Participants

Data for the current study were recorded from 40 healthy adults during their participation in a study that examined the effects of dual-task interference on gait and balance (Johnson, Oram Cardy, Davie, Holmes, Jenkins & Stough, 2012). Participants consisted of 20 men and 20 women ranging in age from 21 to 29 years (*M*=23.90, *SD*= 2.02). All participants were: (a) fluent in English (written and spoken); (b) able to walk 20 feet without assistance; and (c) able to maintain an upright posture for a 10 second period. Participants who had any history of speech or language disorders by self-report were excluded from this study. Due to poor sound quality, 8 of the 40 audio files were eliminated. Therefore data for the current study were recorded from 32 healthy adults, including 18 females and 14 males.

2.2 Instrumentation

A Starkey Soundport Flex Bluetooth headset with flexible boom microphone was used for recording participants' speech. The earpiece portion of the headset was fitted with a fresh piece of gauze for each participant, and the headset was affixed to the participant's ear via an ear hook attached to the headset. Recordings were made using Quicktime Pro software running on a Dell desktop computer, connected to a CRT display, which had been connected via a wireless Bluetooth connection to the headset.

2.3 Procedure

In the walking condition, speech data was collected as participants walked along an instrumented GAITRite ® carpet that spanned 23’ in length. In the standing condition, speech data was collected as participants stood on a biomechanics force platform (Advanced Mechanical Technology Inc., Watertown, USA).

During the original data collection by Johnson et al. (2012), participants were required to repeat a verbal stimulus while walking or while standing still. The verbal stimulus set consisted of eight real-words and eight non-words. Non-word stimuli consisted of phoneme sequences that are possible in the English language, but are not real words. Four of the real-words and four of the non-words were monosyllabic, and the remaining real-words/ non-words were bisyllabic. All stimuli are shown in Table 1 and the stimuli characteristics are described in further detail in the section 2.4 *Characteristics of Verbal Stimuli*. The 16 stimuli were arranged in four randomized experimental blocks: two word lengths (monosyllabic versus bisyllabic) across two lexical conditions (real-word and non-word). Each participant completed the four experimental blocks twice: once while walking and once while standing. Half of the women and half of the men first completed the four blocks (16 stimuli) while walking and then completed the same four blocks while standing. The remaining half of the women and men repeated all of the stimuli while standing first, and then repeated all of the stimuli while walking.

At the onset of each trial, participants were given both a visual and an aural demonstration of the stimulus for that trial via a video. They were then asked to produce a correct repetition of the stimulus for the experimenter. Participants were not provided with any spelling of the stimuli. Any incorrect repetition was corrected by the experimenter and the participant was prompted to repeat the word again. Once a correct production was observed, participants were then asked to either repeat the stimulus continually while standing for ten seconds (in the standing condition) or while walking along the instrumented carpet (in the walking condition). Participants were read the following instructions at the beginning of each trial:

> For this block of trials, we would like you to walk while saying the words we are about to show you. Before each trial, we will show you a clip of a woman saying a word or non-word. This is the sound that you should make (repeatedly) as you walk along the length of the carpet.

Following completion of the walking and standing blocks, participants completed the Inspection Time task on a Dell desktop computer.

Table 1. Verbal stimuli used within experimental blocks

	Monosyllabic	Bisyllabic
Word	toe	today
	bay	photo
	do	tofu
	fee	body
Non-Word	tay	taydee
	foo	footay
	dee	deebaw
	baw	bawfoo

Note: the above spellings are provided for illustrative purposes only – all words were pronounced for participants without presenting any written information

2.4 Characteristics of Verbal Stimuli

The verbal stimuli set was composed of consonants and vowels that formed bisyllabic and monosyllabic real-words and non-words. The stimuli characteristics described below facilitated control of articulatory and phonemic components of the verbal task, including syllable structure, and phoneme combination. All verbal stimuli consisted of the consonant phonemes /b/, /f/, /t/, /d/ and the vowels /a/, /e/ /o/, /u/. When paired together, these consonants and vowels were combined to form both real-word and non-word combinations in monosyllabic and bisyllabic forms. All non–words consisted of the same phonemes and syllable structures as the cognate real-word stimuli, and the non-words were a simple rearrangement of the phonemes and syllable structures found in the real-words. The consonant (C) and vowel (V) phoneme combinations utilized were evenly balanced within word/non-word stimuli. All stimuli contained an open –ended syllable structure, such that all monosyllabic stimuli had a CV structure, while bisyllabic stimuli consisted of a CVCV pattern. The initial syllable of each stimulus across the four conditions and two levels began with each of the four different consonants (/b/, /f/, /t/, /d/). However, a bisyllabic real-word beginning with the phoneme /d/ could not be formed from the phoneme set. As a result, two bisyllabic real words begin with the phoneme /t/. This specific phoneme was chosen because /t/ and /d/ are voiced/ voiceless cognates.

The stimuli were also balanced across word length. Thus, all bisyllabic word stimuli were composed of the same phonemes used in the monosyllabic word stimuli. Phonemes of the monosyllabic non-word stimuli were used an equal amount of times in each syllabic position (initial and final) of the bisyllabic non-words. As a result of the above considerations, all stimuli, with the exception of two bisyllabic real-words beginning with /t/, were balanced across phonemes, syllable structure, lexicality (i.e., real-word versus non-word) and word length (number of syllables). The present study carefully considered results from the previous Johnson et al (2012) study, which suggested that monosyllabic and bisyllabic word lengths are too short to significantly influence gait. Therefore, the present study combined monosyllabic and bisyllabic word lengths since the influence of sex and word meaning on rate of speech in a dual task paradigm were the primary variables of interest.

2.5 Inspection Time Task

This study used the same IT task described by Johnson et al. (2004). The IT task estimates information processing speed, and it was administered separate from the dual-tasks. The IT task was presented using a 17” desktop computer with monitor running at a resolution of 640 x480 pixels. The inspection time stimuli consisted of a cue, followed by a pi image, and then a mask. Participants were first presented with an image of a small filled circle (a cue) for 500 msec. This cue acted as a fixation point for participants. It was immediately followed by one of the two pi images, illustrated in Figure 1. The pi figure was composed of two vertical lines that differed in length. The shorter leg ran 21 millimeters (mm) in length, while the long leg ran 29 mm in length. These two lines were connected at the top by a single horizontal line. This pi image was initially presented for 120 msec, and then subsequent presentation duration was systematically varied based on the accuracy of the participant’s response (described in further detail below). Following the pi image, a lightning mask, consisting of two 29 mm lines was presented for 360 msec. This mask is also depicted in Figure 1.

All participants first completed a practice trial of the IT Task, in which they were required to make judgments of stimuli line length. The trial had a set presentation time of 200 msec and ensured that participants felt confident in their ability to successfully complete the task. Participants were instructed to press the left key if they believed that the left leg was longer and the right key if they believed that the right leg was longer. They were instructed to take as much time as they needed to press the key. Participants completed as many practice trials as needed to correctly identify ten consecutive stimuli.

Taylor and Creelman's (1967) Parameter Estimation by Sequential Testing (PEST) adaptive staircase algorithm was used to systematically alter presentation time on the pi symbol based on the accuracy of the participant's response. Each time the participant responded correctly, the exposure time of the following stimulus would decrease. If the participant responded incorrectly, more exposure time was provided. Therefore, the dependent variable within this task was the presentation time at which the participant consistently achieved 80% accuracy in line length judgment. This dependent variable is considered to be a proxy measure of information processing speed and may therefore potentially reflect an individual's processing capacity. Use of this variable thereby offers a direct assessment method to evaluate the capacity sharing model of dual-task interference.

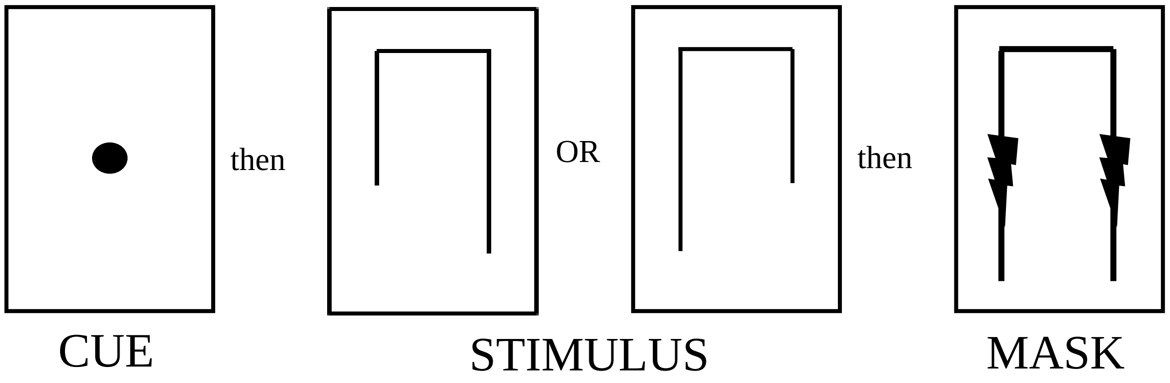
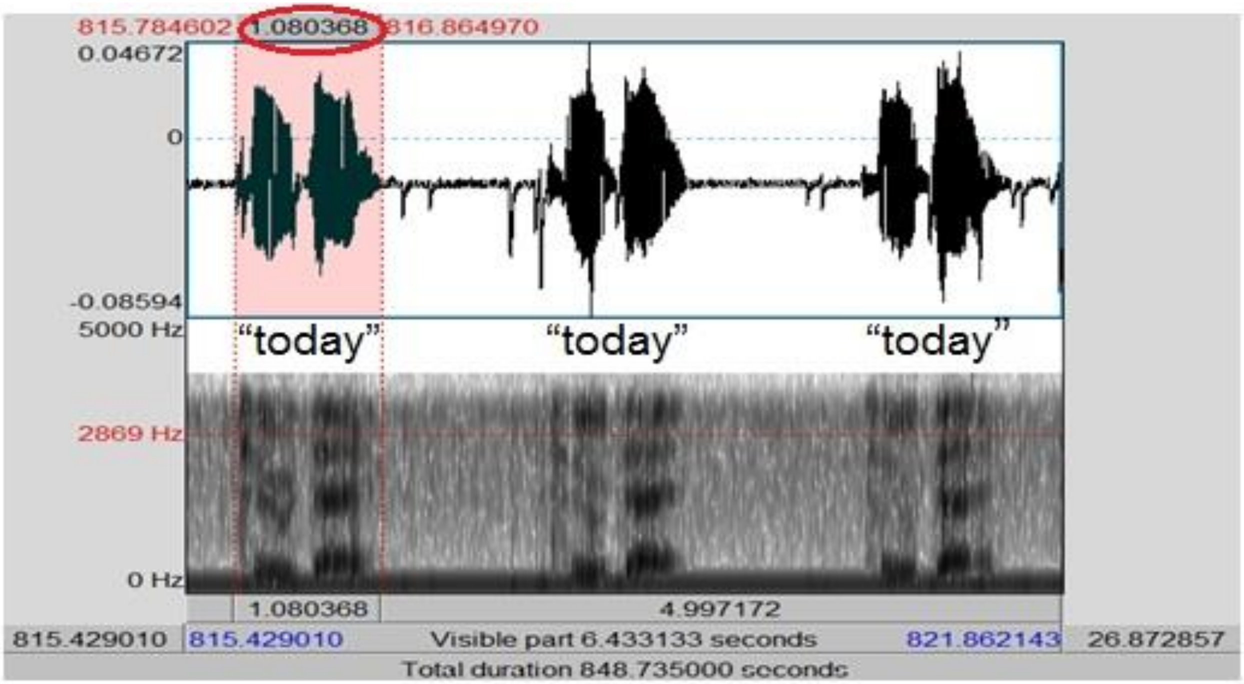


Figure 1. Inspection time task stimuli consisting of a cue, pi image and mask.

2.6 Speech Analysis

Recorded speech data was analyzed using PRAAT (Boersma & Weenink, 2006), a speech analysis program. Oscillograms and spectrograms were generated by PRAAT in order to analyze articulation time in seconds and number and length of pauses in seconds. An example of the editing window displayed in PRAAT is shown in Figure 2. The oscillogram (upper panel) displays the waveform of the sound, while the spectrogram (lower panel) shows the acoustic energy of the sound over time. These visual indicators make speech stimuli more easily identifiable. Using PRAAT's editing window, each individual stimulus was selected and measured by clicking and dragging a cursor from the onset to the offset of a waveform. The duration (in seconds) of this sound selection was then displayed at the top of the oscillogram. To ensure that all stimuli were identified correctly, each speech stimulus measurement was made while listening to a simultaneous audio-signal. In Figure 2, the example stimulus word "today" was measured by placing a cursor at the onset of /t/ and offset of / eɪ/ in "today". The start and finish times of this pink highlighted selection are displayed in red at the top of the window, and the corresponding duration (in seconds) is displayed in black at the top of the bar. This measurement was done for each individual repetition of a stimulus. In our analysis, articulation time and pause time were analyzed separately. They were also combined to produce a "total" speech time measure calculated in seconds. These durational measures (in seconds) were converted and expressed in syllables/second since rate of speech is more commonly expressed as a frequency measure (Goldman- Eisler, 1954,1961; Carroll,1967; Walker & Archibald, 2006). To clarify and to help define our variables of interest, the following section describes the various measures that were obtained during the speech analysis. In order to calculate frequency measures, the following variables were measured:

Figure 2. An example of the editing window displayed in PRAAT displaying a spectro-temporal representation of the bisyllabic word “today” /tudeɪ/.



Note: In this example the red circle indicates the duration of a Stimulus Articulatory Run (“today”) in seconds. Pause Time is measured as the duration of seconds existing between the offset of *eɪ/* and on the onset of */t/*.

Repetitions. The number of Repetitions refers to the number of times a stimulus word was repeated. The number of Repetitions was tallied for each of the 16 stimulus trials, and collapsed across each of the four experimental blocks (i.e., monosyllabic word, monosyllabic non-word, bisyllabic word, bisyllabic non-word).

Articulatory Run. An Articulatory Run is defined and measured as a stretch of speech between two consecutive pauses. Within this study, each individual stimulus was considered an

Articulatory Run. The duration of each Articulatory Run was measured in seconds. The duration of all Articulatory Runs within a trial was calculated in each of the 16 stimulus trials.

Sum Articulation Time. Sum Articulation Time was calculated as the sum of all articulatory runs, collected from each of the 16 stimulus trials, and collapsed across each of the four experimental blocks (e.g., monosyllabic word, monosyllabic non-word, bisyllabic word, and bisyllabic non-word).

Pause Time. Based on Tsao and Weismer (1997), a pause is defined as a disruption of verbal output that lasts at least 150 msec or more. This time criterion clarifies boundaries between a typical stop closure interval (e.g., 70 – 100 msec) and a pause. In the present study, durations less than 150 msec that were not identified as stop closure intervals were defined as “silent intervals”. A pause or a silent interval was measured as the duration of time that existed from the offset of one Articulatory Run to the onset of the next Articulatory Run. For example, if the assigned stimulus was “today”, then the “offset” was recognized as the pulse of the vowel /eɪ/ in “today”, whereas the “onset” was identified as the release of the oral stop /t/ in the following Articulatory Run. The duration of each pause was measured in seconds. The duration of all pause times within a trial was calculated for each of the 16 trials.

Sum Pause Time. Sum Pause Time was calculated as the sum of all pause times, collected from each of the 16 separate trials, and collapsed across each of the four experimental blocks.

Total Speech Time. Finally, Total Speech Time was measured as the combined duration of Sum Articulation Time and Sum Pause Time, collected from each of the 16 separate trials, and collapsed across each of the four experimental blocks.

Frequency

In order to analyze rate of speech using a frequency measure (i.e., syllables/second), Articulation Rate, Pause Rate and Total Speech Rate was calculated for each of the four experimental blocks (i.e., monosyllabic word, monosyllabic non-word, bisyllabic word, and bisyllabic non-word) based on the durational measures obtained and described above.

Articulation Rate. Articulation Rate is defined as the number of syllables produced per second within an experimental block, when pauses are omitted. To calculate the Articulation Rate of a monosyllabic stimulus, the number of Repetitions was divided by Sum Articulation Time to derive a syllable per second value (e.g., if the stimulus word “toe” was repeated 42 times at a Sum Articulation time of 21.33 seconds, then 42 repetitions was divided by 21.33 seconds to derive an Articulation Rate of 1.97 syllables per second). To calculate the Articulation Rate of a bisyllabic stimulus, the number of repetitions was multiplied by 2 and divided by Sum Articulation Time to derive a syllable per second value.

Pause Rate. Pause Rate is defined as the number of pauses produced per second within an experimental block. A pause that was produced after the last Articulatory Repetition (i.e., production of a verbal stimulus) of a trial was not included in Pause Rate calculation. Therefore, the number of Pause Repetitions was calculated as articulatory repetitions minus 1. Our analyses collapsed values across 4 experimental blocks; therefore, the number of Pause Repetitions was calculated as Articulatory Repetitions minus 4. For example, if the stimulus word “toe” was repeated 42 times, than the number of Pause Repetitions would be 38 pauses (i.e., 42-4= 38). In order to calculate Pause Rate, the number of Pause Repetitions was divided by Sum Pause Time to derive a pause per second value (i.e., the stimulus word “toe” was repeated 42 times with Sum

Pause Time of 30.41 seconds; 38 pause repetitions was divided by 30.40 seconds to derive a Pause Rate of 1.25 pauses per second).

Total Speech Rate. Total Speech Rate was calculated as the number of syllables produced per second within an experimental block, when pauses were included. To calculate the Total Speech Rate of both monosyllabic and bisyllabic stimuli, the number of repetitions of each production was divided by Total Speech Time (i.e., Sum Articulation Time combined with Sum Pause Time), to produce a syllable per second value. Therefore, using the "toe" example, 42 repetitions was divided by 51.73 seconds (a Sum Articulation Time of 21.33 seconds combined with a Sum Pause Time of 30.40 seconds) to derive a Total Speech Rate of 0.81 syllables produced per second.

2.7 Statistical Analysis

Four objectives were examined in the present study**.** The first, and primary objective, was to determine the dual-task effects of walking on rate of speech in a healthy young adult population. Included in this objective was the analysis of dual-task effects of walking on speech durational measures, such as pause time, articulation time and total speech time. The second objective examined the influence of word meaning and sex on rate of speech measures in a dual-task paradigm. The third objective investigated the influence of word meaning and sex on speech durational measures in a dual-task paradigm. The fourth objective examined whether participants' speech rate performance, within a dual-task paradigm, was related to their speed of information processing. Included in this objective was a comparison analysis investigating whether participant's speech rate durations were related to their speed of information processing. The statistical procedures are outlined below.

2.7a) Objective 1: Dual- task effects of walking on rate of speech

The primary purpose of this study was to examine the dual-task interference effects of walking on rate of speech in healthy young adults. A series of paired samples t-tests were used to examine differences in speech rate frequency measures (i.e., articulation rate, pause rate, total rate) and speech rate durational measures (i.e., articulation time, pause time, total time) in both the walking and standing conditions. This analysis used an alpha level of 0.05 and was calculated without the Bonferroni correction for the 12 t-tests. The decision to use an uncorrected 0.05 alpha level is based on an attempt to minimize the occurrence of Type II errors that can occur with relatively small sample sizes (n=32) and multiple conditions. Nakagawa (2004) discusses the concern about the risk of type II errors with the use of Bonferroni corrections in studies with small sample sizes. More specifically, the following comparisons were made:

Frequency measures between conditions

1. Articulation rate of non-words: Walking condition versus Standing condition
2. Articulation rate of real-words: Walking condition versus Standing condition
3. Pause rate of non-words: Walking condition versus Standing condition
4. Pause rate of real-words: Walking condition versus Standing condition
5. Total rate of non-words: Walking condition versus Standing condition
6. Total rate of real-words: Walking condition versus Standing condition

Durational measures between conditions

1. Articulation time of non-words: Walking condition versus Standing condition
2. Articulation time of real-words: Walking condition versus Standing condition
3. Pause time of non-words: Walking condition versus Standing condition

4. Pause time of real-words: Walking condition versus Standing condition
5. Total time of non-words: Walking condition versus Standing condition
6. Total time of real-words: Walking condition versus Standing condition

2.7 b) Objective 2: Influence of word meaning and sex on rate of speech (frequency measures)

This objective evaluated the influence of word meaning (i.e., lexicality) and sex on rate of speech while walking and while standing. Two separate, two-way repeated measures multivariate analysis of variance (MANOVAs) were conducted to evaluate: 1. the effect of word meaning and sex on separate rate of speech variables (e.g., articulation rate and pause rate) while walking, and 2. the effect of word meaning and sex on separate rate of speech variables (e.g., articulation rate and pause rate) while standing. For the first analysis, speech rate frequency data from the walking condition was analyzed using a two-way repeated (MANOVA) framework, in which lexical word meaning (real-word versus non-word) served as an independent variable (within subject factor) and sex (male versus female) served as a between subject factor. Speech rate (expressed in syllables/second) served as a dependent variable and was separated into articulation rate (expressed in syllables/second) and pause rate (expressed in pauses/second). Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at experiment-wise alpha of 0.05. For the second analysis, speech rate frequency data from the standing condition was analyzed using a two-way repeated (MANOVA) which utilized the same independent variables (e.g., sex, word meaning) and dependent variables (e.g., articulation rate, pause rate) outlined above. Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at experiment-wise alpha of 0.05.

In addition to these analyses, two separate, two-way repeated measures analysis of variance (ANOVAs) were conducted to evaluate: 1. the effect of word meaning and sex on *total* rate of speech while walking, and 2. the effect of word meaning and sex on *total* rate of speech while standing. For the first analysis, a two-way repeated measures ANOVA examined speech rate frequency data for the walking condition. Within this ANOVA, lexical word meaning (real word versus non-word) served as an independent variable (within subject factor), sex (male versus female) served as a between subject variable, and total speech rate (expressed in syllables/second) served as the dependent variable. The results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at an experiment-wise alpha of 0.05. For the second analysis, speech rate frequency data from the standing condition was analyzed using a two-way repeated ANOVA framework, which utilized the same independent variables (e.g., sex, word meaning) and dependent variable (e.g., total speech rate) outlined above. Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at experiment-wise alpha of 0.05.

2.7 c) Objective 3: Influence of word meaning and sex on speech duration measures

This analysis evaluated the effect of word meaning (i.e., lexicality) and sex on the speech duration of participants while walking and while standing. Two separate, two-way repeated measures MANOVAs were conducted to evaluate: 1. the effect of word meaning and sex on separate speech duration variables (e.g., articulation time and pause time) while walking, and 2. the effect of word meaning and sex on separate speech duration variables (e.g., articulation time and pause time) while standing. For the first analysis, speech duration data was analyzed for the walking condition using a two-way repeated measures MANOVA. Sex was used as a between group independent variable with 2 levels (male and female), while lexicality was used as a within group independent variable with 2 levels (non-word and word). Speech duration (expressed in seconds) served as a dependent variable and was separated into articulation time (expressed in seconds) and pause time (expressed in seconds). Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at an experiment-wise alpha of 0.05. For the second analysis, speech duration data was analyzed for the standing condition using a two-way repeated MANOVA framework, which utilized the same independent variables (e.g., sex, word meaning) and dependent variables (e.g., articulation time, pause time) outlined above. Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at experiment-wise alpha of 0.05.

In addition to these analyses, two separate, two-way repeated measures analysis of variance (ANOVAs) were conducted to evaluate: 1. the effect of word meaning and sex on *total* duration of speech while walking, and 2. the effect of word meaning and sex on *total* duration of speech while standing. For the first analysis, a two-way repeated measures ANOVA was conducted that examined speech duration data for the walking condition. In this ANOVA, lexical word meaning (real word versus non-word) served as an independent variable (within subject factor), sex (male versus female) served as a between subject factor, and total speech time served as a dependent variable. Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at an experiment-wise alpha of 0.05. For the second analysis, speech duration data was analyzed for the standing condition using a two-way repeated ANOVA framework, with the same independent variables (i.e., sex, word meaning) and dependent variable (i.e., total speech duration) outlined above. Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at experiment-wise alpha of 0.05.

2.7 d) Objective 4: Influence of speed of information processing on rate of speech frequency and duration

This analysis was concerned with the extent to which dual-task effects of walking on rate of speech was due to speed of information processing. Past research suggests that speed of information processing can be an indicator of processing capacity and a potential predictor of dual-task interference effects (Johnson et al., 2012). Therefore, an individual’s speech rate performance, within a dual-task paradigm, may be related to his/her speed of information processing. To explore this possibility, two separate, repeated measures multivariate analysis of covariance (MANCOVAs) were conducted to evaluate: 1. the influence of information processing speed on separate rate of speech variables (e.g., articulation rate and pause rate) while walking, and 2. the influence of information processing speed on separate rate of speech variables (e.g., articulation rate and pause rate) while standing. Within the first analysis, the influence of speed of information processed on rate of speech variables while walking was investigated using a MANCOVA. Lexicality served as a within subject independent variable with 2 levels [lexicality: non-word, word] while sex served as a between subject independent variable with 2 levels [sex: male, female]. Total speech rate served as a dependent variable, and was separated into articulation rate and pause rate measures. Lastly, speed of information processing (e.g., inspection time score) was included as a covariate factor. A follow-up univariate analysis of covariance (ANCOVA) was conducted for each of the speech rate components (i.e., articulation rate and pause rate). An effect size estimate was calculated using an omnibus eta square (η^2) statistic, which described the proportion of total variability attributable to a factor or covariate (e.g., the percentage of total variability attributable to the group differences). For the second analysis, the influence of speed of information processing on rate of speech variables was analyzed for the standing condition using a MANCOVA, with the same independent variables (e.g., sex, word meaning), dependent variables (e.g., articulation rate, pause rate) and covariate (e.g., inspection time score) outlined above. A follow-up univariate analysis of covariance (ANCOVA) was conducted for each of the speech rate components (i.e., articulation rate and pause rate). An effect size estimate was calculated using an omnibus eta square (η^2) statistic, which described the proportion of total variability attributable to a factor or covariate (e.g., the percentage of total variability attributable to the group differences).

In addition to these analyses, two separate, two-way repeated measures analysis of covariance (ANCOVA) were conducted to evaluate: 1. the influence of information processing speed on total rate of speech while walking, and 2. the influence of information processing speed on total rate of speech while standing. In the first analysis, total speech rate data were analyzed using a two-way repeated measure analysis of covariance (ANCOVA). Lexicality served as a within subject independent variable with 2 levels [lexicality: non-word, word] while sex served as a between subject independent variable with 2 levels [sex: male, female]. Total speech rate served as a dependent variable. Lastly, speed of information processing (i.e., inspection time score) was included as a covariate factor. Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at an experiment-wise alpha of 0.05. An effect size estimate was calculated using an omnibus eta square (η^2) statistic, which described the proportion of total variability attributable to a factor or covariate (e.g., the percentage of total variability attributable to the group differences)

Durational Speech Measures.

This analysis was concerned with the extent to which dual-task effects of walking on duration of speech was due to speed of information processing. To explore this possibility, two separate, repeated measures multivariate analysis of covariance (MANCOVAs) were conducted to evaluate: 1. the influence of information processing speed on separate speech duration variables (e.g., articulation time and pause time) while walking, and 2. the influence of information processing speed on separate speech duration variables (e.g., articulation time and pause time) while standing. Within the first analysis, the influence of speed of information processed on rate of speech variables while walking was investigated using a MANCOVA. Lexicality served as a within subject independent variable with 2 levels [lexicality: non-word, word] while sex served as a between subject independent variable with 2 levels [sex: male, female]. Total speech time served as a dependent variable, and was separated into articulation time and pause time measures. Lastly, speed of information processing (e.g., inspection time score) was included as a covariate factor. A follow-up univariate analysis of covariance (ANCOVA) was conducted for each of the speech time components (i.e., articulation time and pause time). An effect size estimate was calculated using an omnibus eta square (η^2) statistic, which described the proportion of total variability attributable to a factor or covariate (e.g., the percentage of total variability attributable to the group differences). For the second analysis, the influence of speed of information processing on speech duration variables was analyzed for the standing condition using a MANCOVA, with the same independent variables (e.g., sex, word meaning), dependent variables (e.g., articulation time, pause time) and covariate (e.g., inspection time score) outlined above. A follow-up univariate analysis of covariance (ANCOVA) was conducted for each of the speech duration components (i.e., articulation time and pause time). An effect size estimate was calculated using an omnibus eta square (η^2) statistic, which described the proportion of total variability attributable to a factor or covariate (e.g., the percentage of total variability attributable to the group differences).

In addition to these analyses, two separate, two-way repeated measures analysis of covariance (ANCOVA) were conducted to evaluate: 1. the influence of information processing speed on total speech time while walking, and 2. the influence of information processing speed on total speech time while standing. In the first analysis, total speech time data were analyzed using a two-way repeated measure analysis of covariance (ANCOVA). Lexicality served as a within subject independent variable with 2 levels [lexicality: non-word, word] while sex served as a between subject independent variable with 2 levels [sex: male, female]. Total speech time served as a dependent variable. Lastly, speed of information processing (i.e., inspection time score) was included as a covariate factor. Results from this analysis were interpreted using both univariate and multivariate analyses. All comparisons were made at an experiment-wise alpha of 0.05. An effect size estimate was calculated using an omnibus eta square (η^2) statistic, which described the proportion of total variability attributable to a factor or covariate (e.g., the percentage of total variability attributable to the group differences).

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Chapter 3

3 Results

3.1 Objective 1: Dual-task effects of walking on rate of speech

Frequency Measures. The primary objective of this study was to examine the dual-task interference effects of walking versus standing on rate of speech during the production of real-words and non-words. In order to examine speech frequency measures (i.e., rate of speech) between walking and standing conditions, a series of paired samples t –tests were conducted to compare: 1. average articulation rate (syllables/sec.), 2. pause rate (pauses/sec.) and 3. total speech rate (syllables/sec.) of participants' production of real-words and non-words in both the standing and walking conditions. The descriptive statistics for all frequency measures are presented in Table 2.

Articulation Rate. A two – tailed paired samples t- test analyzed the effects of walking versus standing on articulation rate (syllables/second) during the production of non-words. Results revealed no significant difference in the articulation rate of non-words between walking (*M*=2.64, *SD*=0.60) and standing conditions (*M*=2.56, *SD*=0.53); *t* (31) = (-0.959), *p*= 0.345. A second two-tailed paired samples t-test analyzed the effects of walking versus standing on the articulation rate (syllables/second) during the production of real-words. Results of this analysis revealed no significant difference in the articulation rate of real-words between walking (*M*= 2.40, *SD*=0.53*)* and standing (*M*=2.47, *SD*= 0.56); *t* (31) = (0.896), *p*= 0.377 conditions.

Pause Rate. A two-tailed paired samples t-test was conducted to examine the effects of walking versus standing on the pause rate (pauses/second) during the production of non-words. Results revealed a statistically significant difference in pause rate during the production of non-words between walking and standing conditions. Mean pause rates revealed that when repeating non-words while walking, participants produced 2.76 pauses per second (*SD*=2.08) between stimuli, but only 2.06 pauses per second (*SD*=1.47) between stimuli while standing; *t* (31) = (-3.571), *p* = 0.001. These findings suggest that walking has an effect on participant's pause rate while producing non-words.

A second two-tailed paired samples t-test analyzed the effects of walking versus standing on the pause rate (pauses/second) during the production of real-words. Results of this analysis revealed a statistically significant difference in pause rate between the walking (*M* =2.89, *SD*=2.09) and standing (*M* =2.24, *SD*=1.91) conditions; *t* (31) = (-2.611), *p* = 0.014 during the production of real-words. These findings suggest that walking has an effect on participant's pause rate; specifically, causing participants to increase the number of pauses they produce per second between stimuli.

Total Speech Rate. A two – tailed paired samples t- test analyzed the effects of walking versus standing on total speech rate (articulation rate + pause time) expressed in syllables/second during the production of non-words. Results revealed a statistically significant difference in the total speech rate of non-words between walking and standing conditions. More specifically, when walking, participants produced non-words at a mean total speech rate of 1.09 syllables per second (*SD*=0.35). When standing, participants produced non-words at a mean total speech rate of 0.92 syllables per second (*SD*=0.30); *t* (31) = (-5.384), p = 0.000. These results suggest that the production of non-words while walking has an effect on the number of syllables produced per second in total speech rate measures. Specifically, total speech rate results suggest participants produced non-words faster while walking than when standing.

Similar results were found for the total speech rate production of real words. A two – tailed paired samples t- test analyzed the effects of walking versus standing on total speech rate (articulation rate + pause rate) expressed in syllables/second during the production of real-words. While walking, participants produced a mean total speech rate of 1.04 syllables per second (*SD*= 0.34). While standing, participants produced a mean total speech rate of 0.91 syllables per second (*SD*=0.34). These results demonstrated a statistically significant difference between walking and standing conditions; t (31) = (-3.080), p = 0.004. These findings suggest that producing real-words while walking has an effect on one's total rate of speech. More specifically, these results suggest that during the production of real-words, participants spoke faster while walking versus standing.

Table 2. Means for speech rate frequency measures by condition

		Speech Rate Frequency Measures					
Condition		Articulation Rate Non-word	Articulation Rate Word	Pause Rate Non-word	Pause Rate Word	Total Rate Non-word	Total Rate Word
Standing	Mean	2.56	2.47	2.06	2.24	0.92	0.91
	Std. Deviation	(0.53)	(0.56)	(1.47)	(1.91)	(0.30)	(0.34)
Walking							
	Mean	2.64	2.40	2.76	2.89	1.09	1.04
	Std. Deviation	(0.60)	(0.53)	(2.08)	(2.09)	(0.35)	(0.34)

Note: Articulation Rate and Total Speech Rate are expressed as syllables per second. Pause Rate is expressed as pauses per second. Standard deviations are shown in parentheses below the means.

Durational Speech Measures. In order to examine speech duration measures, a series of paired samples t –tests were conducted to compare: 1. average articulation time (sec.), 2. pause time (sec.) and 3. total time (sec.) of participants' production of real-words and non-words in both the standing and walking conditions. The descriptive statistics for all durational measures are presented in Table 3.

Articulation Time. A two – tailed paired samples t- test analyzed the effects of walking versus standing on articulation time (in seconds) during the production of non-words. Results revealed no significant difference in the articulation time of words in the walking (*M*=0.44, *SD*= 0.09) and standing conditions (*M*=0.43, *SD*= 0.08); *t* (31) = (-1.033), *p*= 0.310 (n.s). A second two-tailed paired samples t-test analyzed the effects of walking versus standing on the articulation time (seconds) during the production of real-words. Results of this analysis revealed no significant difference in the articulation time of non-words in the walking (*M*= 0.41, *SD*=0.09*)* and standing (*M*=0.42, *SD*=0.08) conditions; *t* (31) = (0.666), *p* =0.510 (n.s).

Pause Time. A two-tailed paired samples t-test was conducted to examine the effects of walking versus standing on pause time (seconds) during the production of non-words. Results revealed a statistically significant difference in pause time during the production of non-words in the walking and standing conditions. Mean pause times revealed that, on average, participants paused for 0.68 seconds (*SD* = 0.35) between non-words while standing, but only paused for 0.53 seconds (*SD* = 0.30) between non-words while walking; *t* (31) = (5.058), *p* = 0.000. These findings suggest that during the production of non-words, participants spent more time pausing when standing than when walking.

A second two-tailed paired samples t-test analyzed the effects of walking versus standing on the pause time (seconds) during the production of real-words. Results of this analysis revealed a statistically significant difference in pause time between the walking (*M* =0.53, *SD*=0.30) and standing (*M* =0.68, *SD*=0.35) conditions; *t* (31) = (4.212), *p* = 0.000, during the production of real-words. These findings suggest that during the production of real-words, participants spent more time pausing when standing than when walking.

Total Speech Time. A two – tailed paired samples t- test analyzed the effects of walking versus standing on total speech time (articulation time + pause time) expressed in seconds during the production of non-words. Results show a statistically significant difference in the total speech time of non-words in the walking (*M*=1.12, *SD*= 0.38) and standing conditions (*M*=1.28, *SD*= 0.42); *t* (31) = (4.626), *p*= 0.000. These results suggest that total duration of speech (in seconds) during the production of non-words was longer while standing versus walking.

Similar results were found for the total speech duration of real-words. A two – tailed paired samples t- test analyzed the effects of walking versus standing on total speech time (articulation time + pause time) expressed in seconds during the production of real-words. Results revealed a statistically significant difference in the total speech time between the walking (*M*=1.19, *SD*= 0.40) and standing conditions (*M*=1.32, *SD*= 0.45); *t* (31) = (2.970), *p* = 0.006 during the production of real-words. Therefore, these results suggest that participant’s real word stimuli repetitions had longer durations (in seconds) when standing than when walking.

Table 3. Means for speech duration measures by condition

Condition		Articulation Time Non-word	Articulation Time Word	Pause Time Non-word	Pause Time Word	Total Time Non-word	Total Time Word
		Speech Duration Measures					
Standing	Mean	0.42	0.43	0.68	0.68	1.28	1.32
	Std. Deviation	(0.08)	(0.08)	(0.35)	(0.35)	(0.42)	(0.45)
Walking	Mean	0.41	0.44	0.53	0.53	1.12	1.19
	Std. Deviation	(0.09)	(0.09)	(0.30)	(0.30)	(0.38)	(0.39)

Note: Articulation Time, Pause Time and Total Speech Time are expressed in seconds. Standard deviations are shown in parentheses below the means.

3.2 Objective 2: Influence of word meaning and sex on rate of speech

The purpose of the second objective was to evaluate the influence of word meaning (i.e., lexicality) and sex on rate of speech within a dual-task paradigm. Analyses were conducted for both the walking condition and the standing condition. The following results were found:

Influence of word meaning and sex on articulation rate and pause rate in the walking condition. A two-way repeated measures MANOVA with one between group factor and one within group factor was performed to compare the influence of word meaning and sex on participants' rate of speech while walking. "Sex" was the between group independent variable with 2 levels (male, female) and "lexicality" was the within group independent variable with 2 levels (non-word, real-word). Speech rate (a frequency measure) served as the dependent variable and was separated into articulation rate and pause rate. A multivariate main effect of "sex" approached significance, [*F (*2, 29) =3.186, *p* = 0.056]. See Table 4 for descriptive statistics. The main effect of "sex" is illustrated in Figure 3 with associated means and standard deviations in Table 4. At the univariate level, "sex" significantly influenced pause rate [*F* (1, 30) =6.57, *p* =0.016]. This effect suggests that men and women differed in terms of their pause rate. In particular, women produced approximately 3.52 *(SD* = 2.45) to 3.63 (*SD*=2.42) pauses per second between stimuli, while men produced approximately 1.78 (*SD* = 0.78) to 1.93 (*SD* = 0.98) pauses per second between stimuli. There was a significant main effect of "lexicality", [*F* (2, 29) = 15.544, *p*= 0.000]. The significant main effect of "lexicality" is illustrated in Figure 4 with associated means and standard deviations in Table 5. This result suggests that rate of speech is differentially affected based on word meaning when walking. At the univariate level, "lexicality" was found to have a significant effect on articulation rate [*F* (1, 30) = 29.820, *p*=

0.000,]. See Table 5 for descriptive statistics. This finding suggests that participants articulated significantly faster when repeating non-words (*M* = 2.64, *SD* =0.60) than real words (*M* = 2.40, *SD* = 0.53) when walking. There was no significant interaction between the level of lexicality (i.e., real-word or non-word) and the gender of the participant, on the speech rate variables (i.e., articulation rate and pause rate) while walking [*F (*2, 29) =0.516, *p* = 0.603]. These results suggest that the effect of sex on pause rate does not depend on the word meaning of the stimuli. These results also suggest that the effect of word meaning on both articulation rate and pause rate does not depend on the participant's sex.

Table 4. Means for speech rate frequency measures by sex in the walking condition.

		Speech Rate Frequency Measures					
Sex		Articulation Rate Non-word	Articulation Rate Word	Pause Rate Non-word	Pause Rate Word	Total Rate Non-word	Total Rate Word
Women							
	Mean	2.71	2.51	3.52	3.63	1.21	1.16
	Std. Deviation	(0.62)	(0.57)	(2.45)	(2.42)	(0.35)	(0.35)
Men	Mean	2.56	2.26	1.78	1.93	0.95	0.89
	Std. Deviation	(0.58)	(0.46)	(0.78)	(0.98)	(0.29)	(0.26)

Note: Articulation Rate and Total Rate are expressed as syllables per second. Pause Rate is expressed as pauses per second. Standard deviations are shown in parentheses below the means.

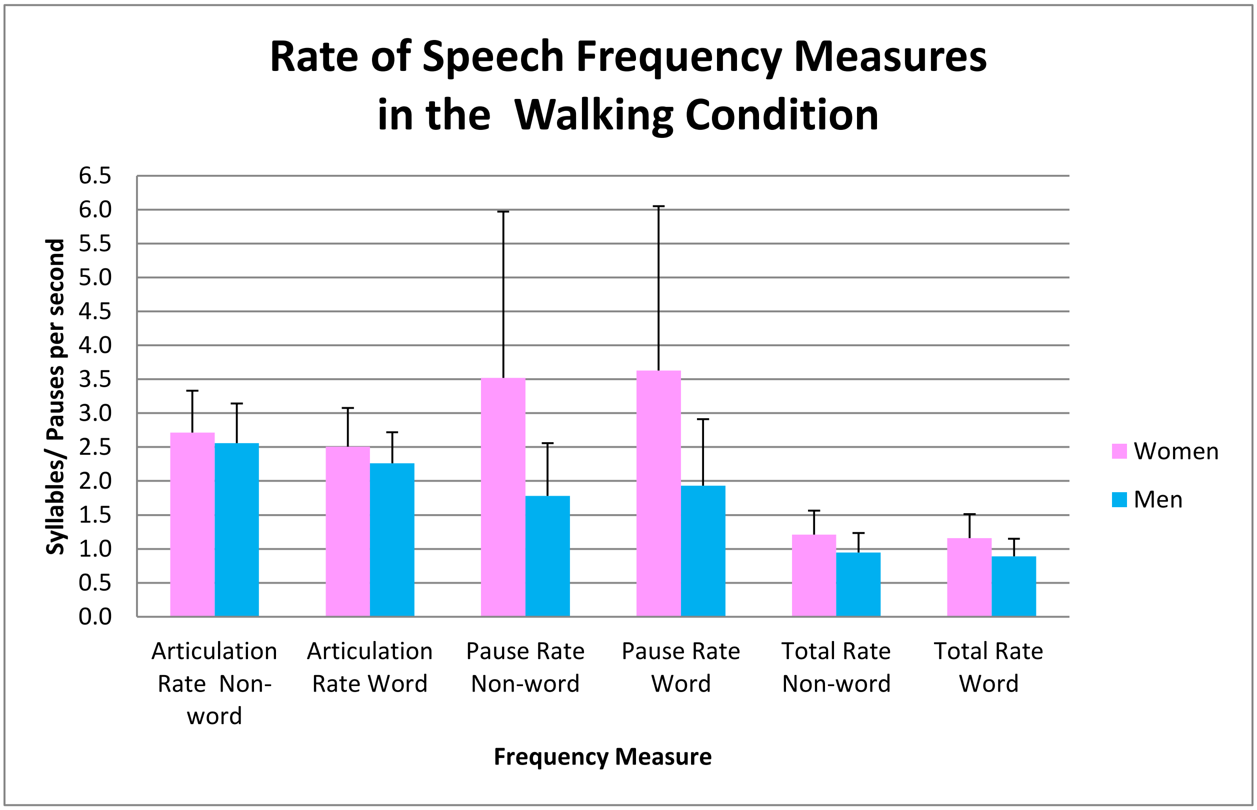

Figure 3. Mean speech rate frequency measures by sex in the walking condition

Note: Standard deviations are expressed through error bars.

Table 5. Means for speech rate frequency measures by word meaning in the walking condition

		Speech Frequency Measures		
Lexicality		Articulation Rate	Pause Rate	Total Rate
Non-word	Mean	2.65	2.76	1.09
	Std. Deviation	(0.60)	(2.07)	(0.35)
Words	Mean	2.40	2.89	1.04
	Std. Deviation	(0.53)	(2.08)	(0.34)

Note: Articulation Rate and Total Rate are expressed as syllables per second. Pause Rate is expressed as pauses per second. Standard deviations are shown in parentheses below the means.

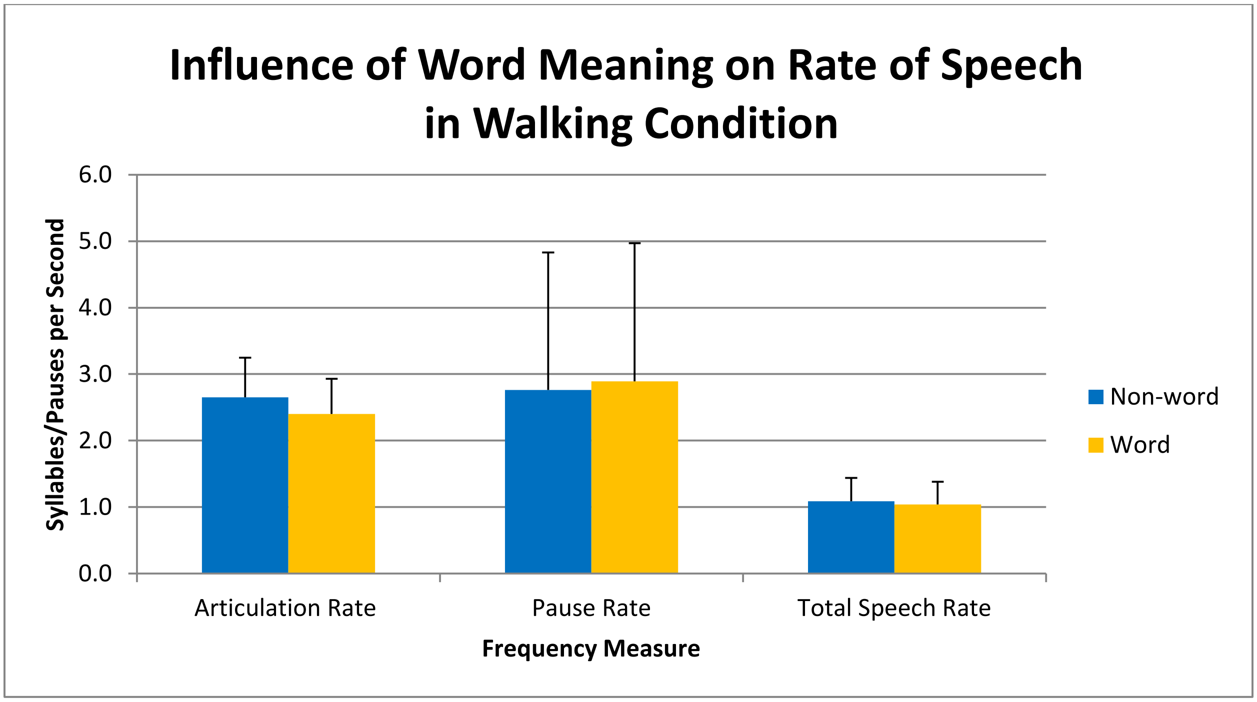

Figure 4. Mean speech rate frequency by word meaning in the walking condition

Note: Standard deviations are expressed through error bars.

Influence of word meaning and sex on total speech rate in the walking condition. Speech rate is often expressed as "Total Speech Rate", a frequency measure which includes pauses in the overall calculation of rate of speech. A second two-way repeated measures ANOVA with one between group factor ("sex") and one within group factor ("lexicality") was conducted to compare the influence of sex and word meaning on participants' total speech rate (i.e., articulation rate + pause rate, expressed in syllables/second) while walking. Each of the independent variables (sex, lexicality) had 2 levels [sex: male, female; lexicality: non-word, real word]. Rate of speech, defined as "Total Speech Rate", served as a dependent variable. Results of this analysis showed a significant main effect of "sex" on total speech rate between men and women [$F(1, 30) = 5.549$, $p = 0.025$]. The main effect of "Sex" on total speech rate is illustrated in Figure 3 with associated means and standard deviations in Table 4. This effect suggests that men and women differed in terms of their total speech rate. On average, women produced 1.16 (*SD*= 0.35) to 1.21 (*SD*=0.35) syllables per second while walking, while men produced 0.89 (*SD*=0.26) to 0.95 (*SD*=0.29) syllables per second while walking. There was also a significant main effect of "lexicality" on total speech rate [$F(1, 30) = 10.125$, $p = 0.003$]. The significant effect of "lexicality" on total speech rate is illustrated in Figure 4 with associated means and standard deviations in Table 5. This result suggests that, regardless of sex, participants had a faster total speech rate (in syllables per second) when producing non-words [*M*=1.09, *SD*= 0.35] versus real words [*M* =1.04, *SD* = 0.34]. While walking, there was no significant interaction between the level of lexicality (i.e., real-word or non-word) and the sex of the participant, on total rate of speech. [$F(1, 30) = 0.052$, $p = 0.821$]. Therefore, these results suggest that the effect of sex on total rate of speech while walking does not depend on the word meaning of the stimuli.

These results also suggest that the effect of word meaning on total rate of speech while walking does not depend on the sex of the participant.

Influence of word meaning and sex on articulation rate and pause rate in the standing condition. A two-way repeated measures MANOVA with one between group factor and one within group factor was performed to compare the influence of word meaning and sex on participants' rate of speech while standing. "Sex" was used as the between group independent variable with 2 levels (male, female) and "lexicality" was used as the within group independent variable with 2 levels (non-word, real word). Speech rate, a frequency measure, served as the dependent variable and was separated into articulation rate and pause rate. Results showed a significant main effect of "sex" [*F* (2, 29) = 3.382, *p*= 0.048]. See Table 6 for descriptive statistics. The effect of "sex" is illustrated in Figure 5 with associated means and standard deviations in Table 6. At the univariate level, the effects of "sex" on participant pause rate approached significance [*F* (1, 30) = 3.997, *p*= 0.055]. These effects suggest that men and women differed in terms of their pause rate. On average, women produced 2.50 (*SD*=1.77) to 2.80 (*SD*=2.35) pauses per second between stimuli, while men produced 1.50 (*SD*=0.64) to 1.51 (*SD*=0.69) pauses per second between stimuli. Women There was no significant main effect of "lexicality" found in the standing condition [*F* (2, 29) = 1.969, *p*= 0.158]. See Table 7 for descriptive statistics. While standing, results showed no significant interaction between lexicality (i.e., real-word or non-word) and the sex of the participant, on rate of speech variables (i.e., articulation rate and pause rate) [*F* (2, 29) = 0.926, *p*= 0.407]. Therefore, the results suggest that the effect of sex on pause rate while standing does not depend on the word meaning of the stimuli.

Table 6. Means for speech rate frequency measures by sex in the standing condition

		Speech Rate Frequency Measures					
Sex		Articulation Rate Non-word	Articulation Rate Word	Pause Rate Non-word	Pause Rate Word	Total Rate Non-word	Total Rate Word
Women	Mean	2.55	2.47	2.50	2.80	1.00	1.00
	Std. Deviation	(0.47)	(0.50)	(1.77)	(2.35)	(0.33)	(0.37)
Men	Mean	2.57	2.47	1.50	1.51	0.82	0.81
	Std. Deviation	(0.62)	(0.65)	(0.64)	(0.69)	(0.24)	(0.27)

Note: Articulation Rate and Total Rate are expressed as syllables per second. Pause Rate is expressed as pauses per second. Standard deviations are shown in parentheses below the means.

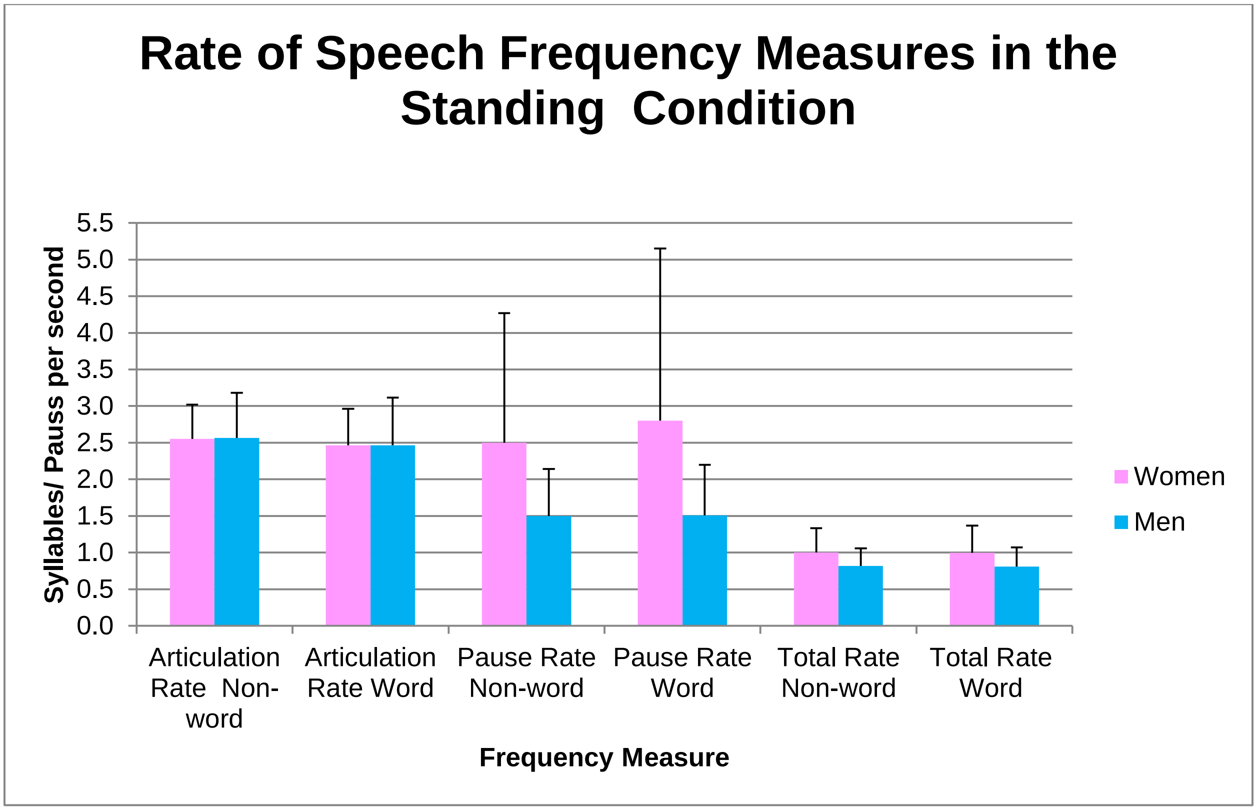

Figure 5. Mean speech rate frequency measures by sex in the standing condition

Note: Standard deviations are expressed through error bars.

Table 7. Means for speech rate frequency measures by word meaning in the standing condition

		Speech Frequency Measures		
Lexicality		Articulation Rate	Pause Rate	Total Rate
Non-word	Mean	2.56	2.06	0.92
	Std. Deviation	(0.53)	(1.47)	(0.30)
Words	Mean	2.46	2.24	0.91
	Std. Deviation	(0.56)	(1.91)	(0.34)

Note: Articulation Rate and Total Rate are expressed as syllables per second. Pause Rate is expressed as pauses per second. Standard deviations are shown in parentheses below the means.

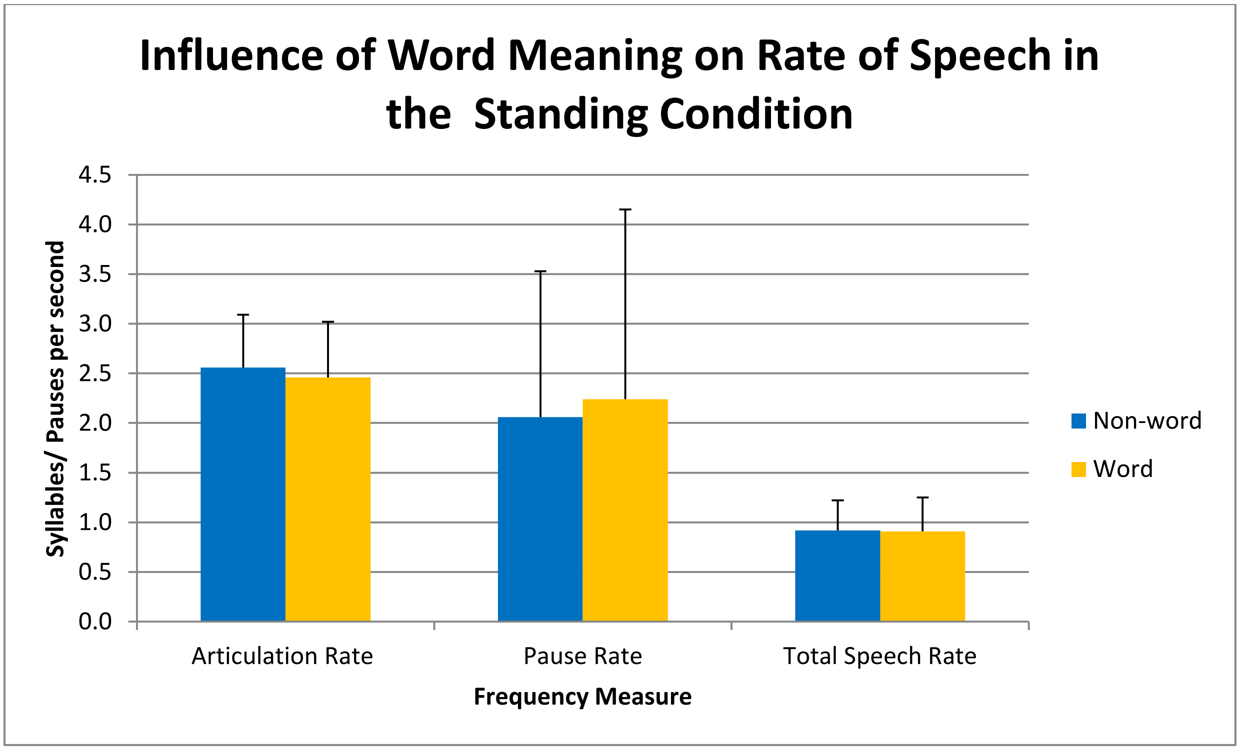

Figure 6. Mean speech rate frequency measures by word meaning the standing condition

Note: Standard deviations are expressed through error bars.

Influence of word meaning and sex on total speech rate in the standing condition. A two-way repeated measures ANOVA with one between group factor ("sex") and one within group factor ("lexicality") was conducted to compare the influence of sex and word meaning on participants' total rate of speech while standing. Each of the independent variables (sex, lexicality) had 2 levels [sex: male, female; lexicality: non-word, real word]. "Total Speech Rate", a frequency measure, served as the dependent variable. Results of this analysis revealed no statistically significant effect of sex [F (1, 30) =2.857, p = 0.101] or "lexicality" [F (1, 30) =0.133, p = 0.718] on total speech rate. See Table 6 for descriptive statistics of sex. See Table 7 and Figure 6 for the descriptive statistics and illustration of word meaning. There was also no significant interaction between the effects of "sex" and "lexicality" on total speech rate while standing [F (1, 30) =0.038, p = 0.846]. Therefore, the effect of sex on total rate of speech while standing does not depend on the word meaning of the stimuli. Likewise, the effect of word meaning on total rate of speech while standing does not depend on the sex of the participant.

3.3 Objective 3: Influence of word meaning and sex on speech durational measures

The purpose of the third objective was to evaluate the influence word meaning (i.e., lexicality) and sex on duration of speech within a dual-task paradigm. Analyses were conducted for both the walking condition and the standing condition. The following results were found:

Influence of word meaning and sex on articulation time and pause time in the walking condition. A two-way repeated measures MANOVA with one between group factor and one within group factor was performed to compare the influence of word meaning and sex on participant's duration of speech while walking. "Sex" was the between group independent variable with 2 levels (male, female) and "lexicality" was the within group independent variable with 2 levels (non-word, real-word). Speech time, a duration measure, served as the dependent variable and was separated into articulation time and pause time. A multivariate main effect of "sex" was significant [*F (*2, 29) =4.123, *p* = 0.027]. See Table 8 for descriptive statistics. The main effect of "sex" is illustrated in Figure 7 with associated means and standard deviations in Table 8. This result suggests that the durational aspects of speech are differentially affected based on one's gender. At the univariate level, "sex" significantly influenced participant pause times [*F* (1, 30) =8.501, *p* =0.007]. This finding suggests that men and women differ in terms of pause time (i.e., the number of seconds spent pausing between stimuli). Women spent approximately 0.40 (*SD* = 0.19) and 0.42 (*SD*=0.21) seconds pausing between stimuli, while men spent 0.69 (*SD* = 0.34) and 0.68 (*SD* = 0.34) seconds pausing between stimuli. There was also a significant main effect of "lexicality" [*F* (2, 29) = 14.750, *p*= 0.000]. The significant main effect of "lexicality" is illustrated in Figure 8 with associated means and standard deviations in Table 9. This result suggests that the durational aspects of speech are differentially affected based on word meaning. At the univariate level, "lexicality" significantly affected articulation time [*F* (1, 30) = 28.663, *p*= 0.000]. See Table 9 for descriptive statistics. This result suggests that participants spent significantly fewer seconds producing non-words (*M* = 0.41, *SD* =0.09) than real-words (*M* = 0.44, *SD* = 0.09) when walking. See Table 9 for descriptive statistics. While walking, there was no significant interaction between the level of lexicality (i.e., real-word or non-word) and the gender of the participant, on the durational speech measures (i.e., articulation time and pause time) [*F (*2, 29) =0.576, *p* = 0.568]. These results suggest that the effect of sex on pause time does not depend on the word meaning of the stimuli. Results also suggest that the effect of word meaning on articulation time does not depend on the participant's sex.

Table 8. Means for speech duration measures by sex in the walking condition

Sex		Speech Duration Measures					
		Articulation Time Non-word	Articulation Time Word	Pause Time Non-word	Pause Time Word	Total Time Non-word	Total Time Word
Women	Mean	0.40	0.42	0.40	0.42	0.97	1.04
	Std. Deviation	(0.10)	(0.09)	(0.19)	(0.21)	(0.30)	(0.29)
Men	Mean	0.43	0.47	0.69	0.68	1.30	1.37
	Std. Deviation	(0.08)	(0.09)	(0.34)	(0.34)	(0.42)	(0.44)

Note: Articulation Time, Pause Time and Total Time are expressed in seconds. Standard deviations are shown in parentheses below the means.

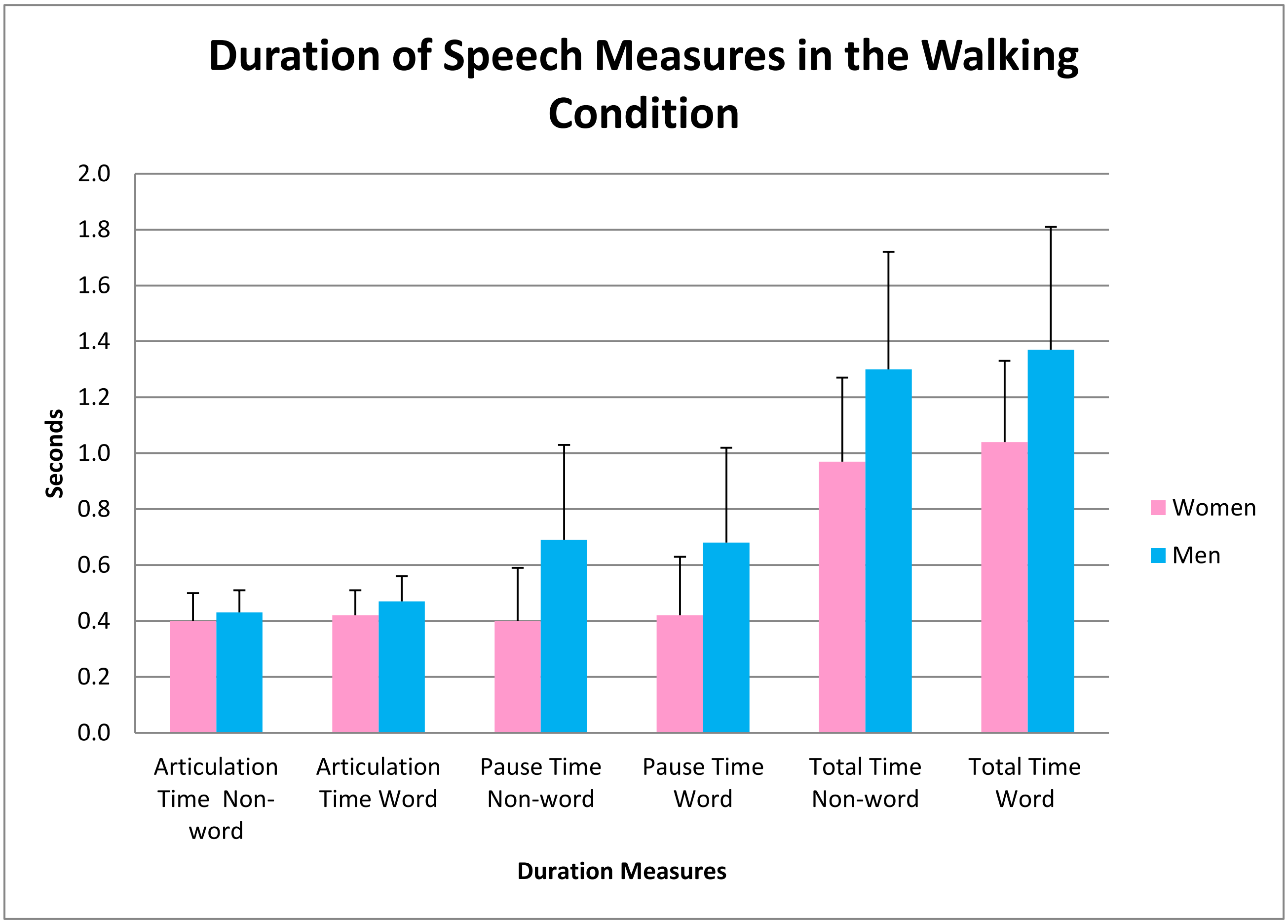

Figure 7. Means of speech duration measures by sex in the walking condition

Note: Standard deviations are expressed through error bars.

Table 9. Means for speech duration measures by word meaning in the walking condition

		Speech Duration Measures		
Lexicality		Articulation Time	Pause Time	Total Time
Non-word	Mean	0.41	0.53	1.12
	Std. Deviation	(0.09)	(0.30)	(0.38)
Words	Mean	0.44	0.53	1.19
	Std. Deviation	(0.09)	(0.30)	(0.39)

Note: Articulation Time, Pause Time and Total Time are expressed in seconds. Standard deviations are shown in parentheses below the means.

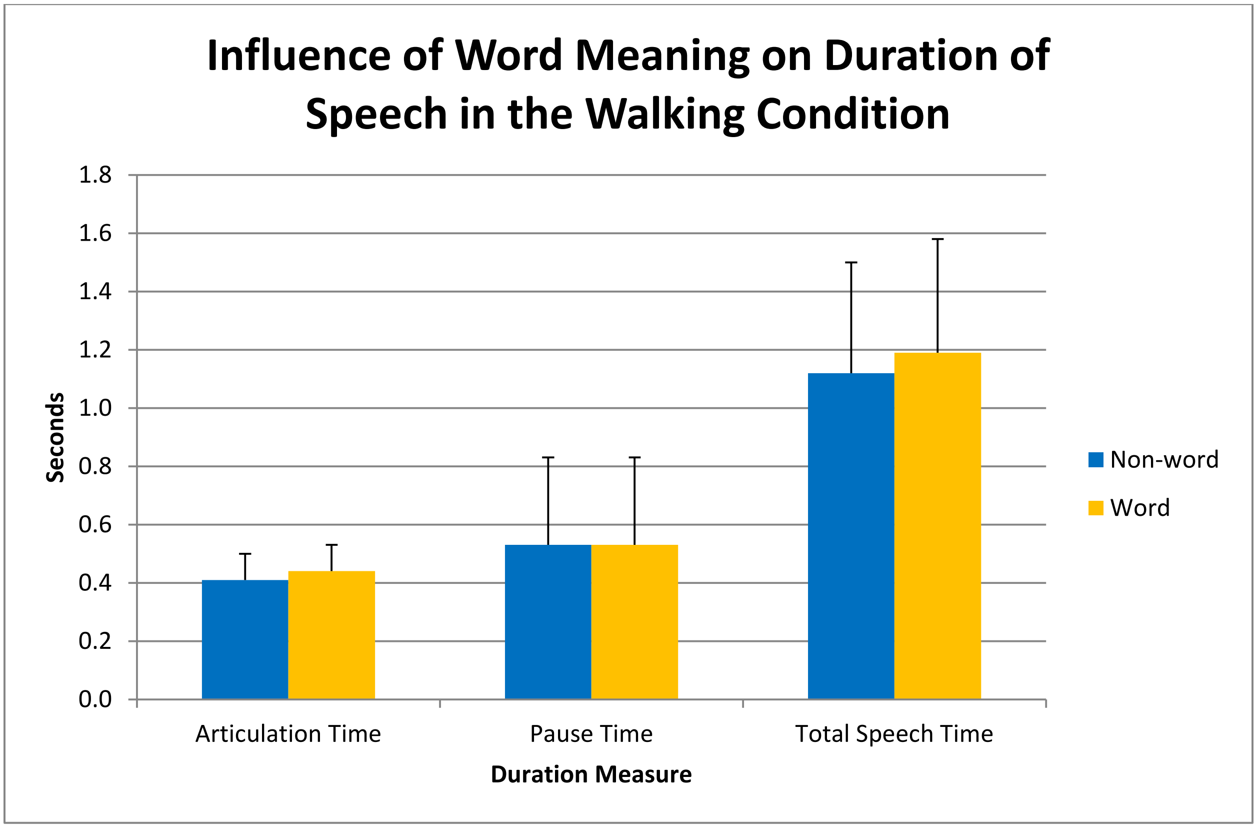

Figure 8. Means of speech duration measures by word meaning in the walking condition

Note: Standard deviations are expressed through error bars.

Influence of word meaning and sex on total speech duration in the walking condition. Speech duration can be expressed as "Total Speech Time", a durational measure which includes pause time in the overall calculation of duration of speech. A second two-way repeated measures ANOVA with one between group factor ("sex") and one within group factor ("lexicality") was conducted to compare the influence of sex and word meaning participants' total speech duration (i.e., articulation time + pause time, expressed in syllables/second) while walking. Each of the independent variables (sex, lexicality) had 2 levels [sex: male, female; lexicality: non-word, real word]. Duration of speech, defined as "Total Speech Time", served as a dependent variable. Results of this analysis revealed a significant main effect of "sex" on total speech time between men and women [F $(1, 30) = 6.975$, $p = 0.013$]. The main effect of "sex" on total speech time is illustrated in Figure 7 with associated means and standard deviations in Table 8. This result suggests that men and women differed in their total rate of speech. In particular, women produced 0.97 (*SD*=0.30) to 1.04 (*SD*=0.29) syllables per second while walking. In comparison, men produced 1.30 (*SD*=0.42) to 1.37 (*SD*=0.44) syllables per second while walking. There was also a significant main effect of "lexicality" on total speech time [F $(1, 30) = 11.458$, $p = 0.002$]. The significant effect of "lexicality" on total speech time is illustrated in Figure 8 with associated means and standard deviations in Table 9. This result suggests that participants spent fewer seconds repeating non-words [M=1.12, *SD*=0.38] in comparison to real words [M=1.19, *SD*=0.39]. There was no significant interaction between the level of lexicality (i.e., real-word or non-word) and the gender of the participant, on participants' total speech time while walking [F $(1, 30) = 0.016$, $p = 0.901$]. These results suggest that the effect of sex on total speech time does not depend on the word meaning of the stimuli. These results also suggest that the effect of word meaning on total speech time does not depend on the participant's sex.

Influence of word meaning and sex on articulation time and pause time in the standing condition. A two-way repeated measures ANOVA with one between group factor and one within group factor was performed to compare the influence of word meaning and sex on participants' duration of speech while standing. "Sex" was used as the between group independent variable with 2 levels (male, female) and "lexicality" was used as the within group independent variable with 2 levels (non-word, real word). Speech time, a duration measure, served as the dependent variable and was separated into articulation time and pause time. There was no main effect of "sex" [F (2, 29) = 2.874, *p*= .083] or "lexicality" [*F* (2 29) = 1.024, *p* = 0.372]; however, at the univariate level, results suggest a significant effect of "sex" between men and women's pause times [*F* (1, 30) = 5.232, *p*= 0.029]. See Table 10 for descriptive statistics. The univariate effect of "sex" is illustrated in Figure 9 with associated means and standard deviations in Table 10. These results suggest that men and women differed in terms of their pause time. Specifically, women, spent 0.56 (*SD* = 0.26) to 0.57 (*SD*=0.26) seconds pausing between stimuli, while men spent 0.83 (*SD* = 0.42) to 0.84 (*SD* = 0.41) seconds pausing between stimuli. There was no univariate effect of "lexicality" found within the standing condition [*F* (2, 29) = 1.969, *p*= 0.158]. See Table 11 and Figure 10 for descriptive statistics. There was no significant interaction between the level of lexicality (i.e., real-word or non-word) and the sex of the participant, on the rate of speech durational measures (i.e., articulation time and pause time) while standing [*F* (2, 29) = 0.926, *p*= 0.407]. Therefore, these results suggest that the effect of sex on pause time while standing does not depend on the word meaning of the stimuli.

Table 10. Means for speech duration measures by sex in the standing condition

		Speech Duration Measures					
Sex		Articulation Time Non-word	Articulation Time Word	Pause Time Non-word	Pause Time Word	Total Time Non-word	Total Time Word
Women	Mean	0.41	0.43	0.57	0.56	1.17	1.19
	Std. Deviation	(0.08)	(0.09)	(0.26)	(0.26)	(0.35)	(0.35)
Men	Mean	0.43	0.44	0.83	0.84	1.43	1.48
	Std. Deviation	(0.09)	(0.09)	(0.42)	(0.41)	(0.46)	(0.51)

Note: Articulation Time, Pause Time and Total Time are expressed in seconds. Standard deviations are shown in parentheses below the means.

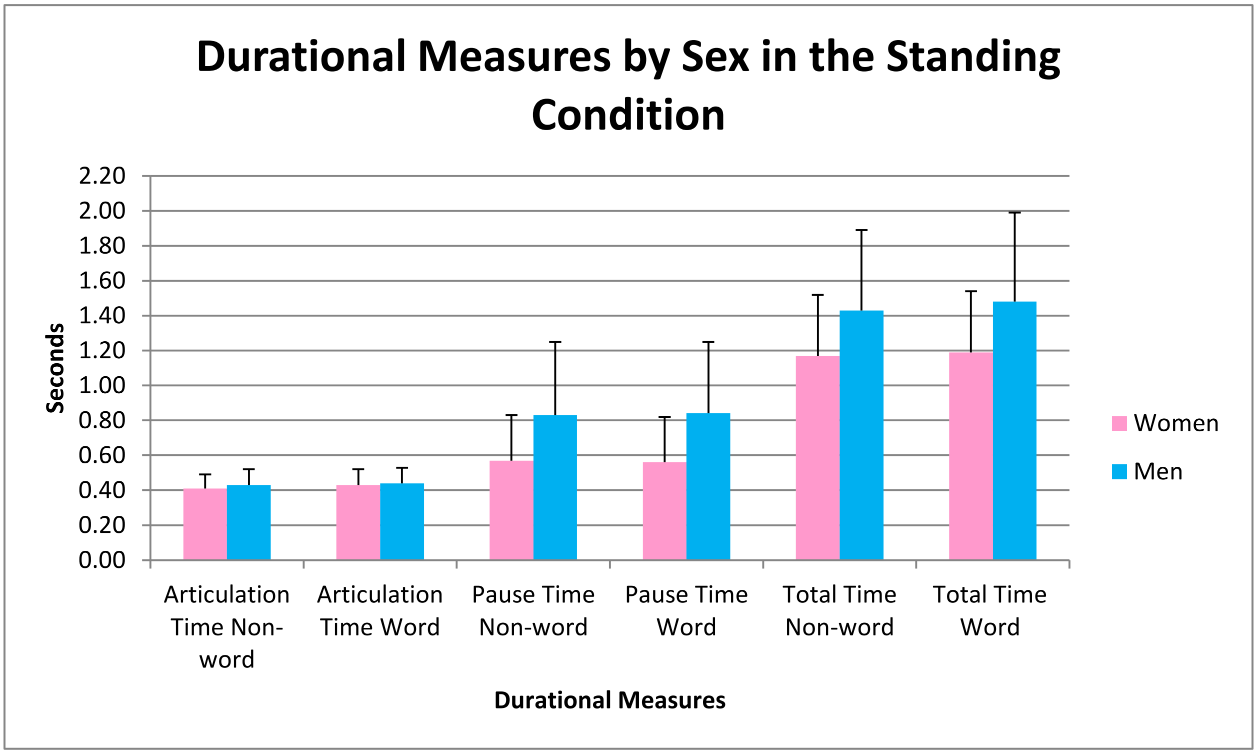

Figure 9. Means of duration measures by sex in the standing condition.

Note: Standard deviations are expressed through error bars.

Table 11. Means for speech duration measures by word meaning in the standing condition

		Speech Duration Measures		
Lexicality		Articulation Time	Pause Time	Total Time
Non-word	Mean	0.42	0.68	1.28
	Std. Deviation	(0.08)	(0.35)	(0.42)
Words	Mean	0.43	0.68	1.32
	Std. Deviation	(0.08)	(0.35)	(0.45)

Note: Articulation Time, Pause Time and Total Time are expressed in seconds. Standard deviations are shown in parentheses below the means.

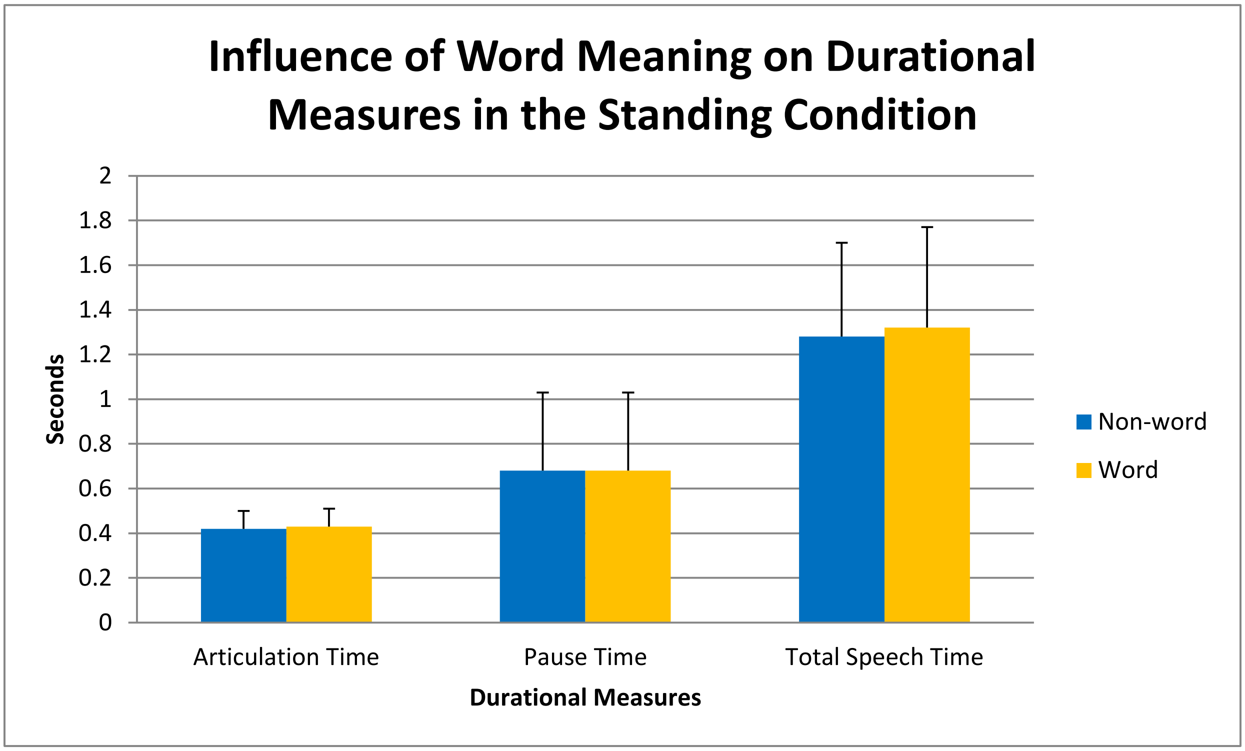

Figure 10. Means of speech duration measures by word meaning in the standing condition

Note: Standard deviations are expressed through error bars.

Influence of word meaning and sex on total speech time in the standing condition. A two-way repeated measures ANOVA with one between group factor (“sex”) and one within group factor (“lexicality”) was conducted to compare the influence of sex and word meaning on participants’ duration of speech while standing. Each of the independent variables (sex, lexicality) had 2 levels [sex: male, female; lexicality: non-word, real word]. “Total Speech Time”, a durational measure, served as a dependent variable. Results of this analysis revealed no statistically significant main effects of sex [F (1, 30) =2.857, p = 0.101] on total speech time (See Table 10 for descriptive statistics of sex). There was also no statistically significant effect of “lexicality” [F (1, 30) =0.133, p = 0.718] on total speech time (See Table 11 and Figure 10 for descriptive statistics). Finally, there was no significant interaction between the level of lexicality (i.e., real-word or non-word) and the gender of the participant, on total speech time while standing [F (1, 30) =0.038, p = 0.846]. Therefore, these results suggest that neither sex nor word meaning significantly influence total speech time while standing.

3.4 Objective 4: Influence of speed of information processing on rate of speech

Frequency Measures. The purpose of the fourth objective was to evaluate the extent to which dual-task effects on rate of speech were due to speed of information processing. Statistical analyses evaluated articulation rate, pause rate, and total speech rate along with inspection time task scores. These analyses were conducted for both the walking condition and the standing condition. The following results were found:

Influence of speed of information processing on articulation rate and pause rate in the walking condition. A repeated measure multivariate analysis of covariance (MANCOVA) was conducted to evaluate the influence of speed of information processing on men and women's separate rate of speech variables (e.g., articulation rate and pause rate) while walking. "Sex" served as a between group independent variable with 2 levels (male, female) and "lexicality" served as a within group independent variable with 2 levels (non-word, real word). Total speech rate (a frequency measure) served as a dependent variable and was broken down into articulation rate and pause rate measures. Speed of information processing (i.e., inspection time score) was included as a covariate factor.

Appendix A shows the results of the MANCOVA when the inspection time covariate was controlled for. This table indicates that the covariate (IT) did not significantly predict either of the dependent variables; articulation rate [F (1, 29) = 0.749, p= 0.394, $\eta^2_{partial}$ = 0.025] or pause rate [F (1, 29) = 0.125, p= 0.726, $\eta^2_{partial}$ = 0.004]. Therefore, the articulation rate and pause rate of real-words and non-words were not influenced by a participant's inspection time score. Appendix B displays the multivariate effects of this MANCOVA, which suggests that, after controlling for inspection time, there were no multivariate effects of lexicality, lexicality interacting with IT scores, or lexicality interacting with sex on articulation rate or pause rate. There was, however, a univariate effect of lexicality on articulation rate [F (1, 29) = 4.050, p = 0.054, $\eta^2_{partial}$ = 0.123] (Appendix C). Estimated marginal means indicated that non-words (M=2.63) were repeated more often than real words (M= 2.38). Therefore, all participants were able to produce non-words more quickly than real-words while walking. Interestingly, after the potential effects of individual speed of information processing (IT score) were removed, there was a statistically significant effect of sex on participants' pause rates [F (1, 29) = 6.342, p =

0.018, $\eta^2_{partial}$ = 0.180]. Therefore, these results suggest that there was a significant effect of sex on pause rate after controlling for individual speed of information processing, and sex was accountable for 18 % of the variability in pause rate frequencies between men and women.

Influence of speed of information processing on total speech rate in the walking condition. A repeated measures analysis of covariance (ANCOVA) was conducted to evaluate the influence of speed of information processing on men and women's separate total speech rate while walking. "Sex" served as a between group independent variable with 2 levels (male, female), "lexicality" served as a within group independent variable with 2 levels (non-word, real word) and total speech rate (a frequency measure) served as a dependent variable. Speed of information processing (i.e., inspection time score) was included as a covariate factor.

Appendix D depicts the results of an ANCOVA when the inspection time covariate was included. Appendix E shows the multivariate results from this ANCOVA and demonstrates that, after controlling for inspection time, there were no multivariate effects of lexicality, lexicality interacting with IT score, or lexicality interacting with sex on total rate of speech. At the univariate level, results shown in Appendix D, indicate that although inspection time was not a significant predictor of total speech rate frequency [F (1, 29) = 0.551, p= 0.464, $\eta^2_{partial}$ = 0.019], sex had a significant effect on participants' total rate of speech *[F* (1, 29) = 6.015, p= 0.020, $\eta^2_{partial}$ = 0.172]. Therefore, 17.2 % of the variability in total rate of speech could be predicted by the sex of the participant.

Influence of speed of information processing on articulation rate and pause rate in the standing condition. A repeated measure multivariate analysis of covariance (MANCOVA) was conducted to evaluate the influence of speed of information processing on men and women's separate rate of speech variables (i.e., articulation rate and pause rate) while standing. "Sex" served as a between group independent variable with 2 levels (male, female) and "lexicality" served as a within group independent variable with 2 levels (non-word, real word). Total speech rate (a frequency measure) served as a dependent variable and was broken down into articulation rate and pause rate variables. Speed of information processing (i.e., inspection time score) was included as a covariate factor.

Appendix F shows the results of the MANCOVA when the inspection time covariate was controlled for. Results from this MANCOVA suggest that, after controlling for inspection time, there were no multivariate effects of lexicality, lexicality interacting with IT scores, or lexicality interacting with sex on articulation rate or pause rate (Appendix G). Contrary to the walking condition, Appendix H shows that there were also no significant univariate effects of lexicality on articulation rate [F (1, 29) =0.716, p=0.404, $\eta^2_{partial}$ =0.024] while standing. Estimated marginal means support this finding, indicating that non-words (M=2.54) and real words (M=2.46) were repeated at similar frequencies. Therefore, all participants appeared to articulate non-words and real words at a similar rate while standing. Results from the MANCOVA (Appendix F) also indicate that the covariate (IT) did not significantly predict the dependent variables, articulation rate [F (1, 29) = 0.946, p= 0.339, $\eta^2_{partial}$ = 0.032] or pause rate [F (1, 29) = 0.776, p= 0.386, $\eta^2_{partial}$ = 0.026]. Therefore, the articulation rate and pause rate of real-words and non-words were not influenced by a participant's inspection time score. Of particular interest, however, is that when the potential effects of individual processing capacity (IT score) were removed, the effect of sex remained statistically significant (p =0.039). More specifically, the effect of sex influenced participants' pause rates [F (1, 29) = 4.673, p = 0.039, $\eta^2_{partial}$ = 0.139]. Therefore, these results suggest that the effect of sex on pause rates was statistically significant after controlling for individual speed of information processing (p=0.039). These results also suggest that after controlling for processing speed, sex was accountable for approximately 14 % of the variability in pause rate frequencies between men and women.

Influence of information processing speed on total speech rate in the standing condition. A repeated measures analysis of covariance (ANCOVA) was conducted to evaluate the influence of speed of information processing on men and women's separate total speech rate while standing. "Sex" served as a between group independent variable with 2 levels (male, female), "lexicality" served as a within group independent variable with 2 levels (non-word, real word) and total speech rate (a frequency measure) served as a dependent variable. Speed of information processing (i.e., inspection time score) was included as a covariate factor.

Appendix I displays the results of an ANCOVA when the inspection time covariate was included. Results from this ANCOVA indicate that, after controlling for inspection time, there were no multivariate effects of lexicality, lexicality interacting with IT score, or lexicality interacting with sex on total rate of speech. At the univariate level, results indicate that inspection time was not a significant predictor of total speech rate frequency [F (1, 29) = 0.967, p= 0.334, $\eta^2_{partial}$ = 0.032] and sex had no significant effect on participants' total rate of speech [F (1, 29) = 3.618, p= 0.067, $\eta^2_{partial}$ = 0.111] (Appendix I). Therefore, neither inspection time nor sex could predict the variability in total rate of speech while standing.

Durational Measures. The fourth objective also evaluated the extent to which dual-task effects on duration of speech were due to speed of information processing. Statistical analyses evaluated articulation time, pause time, and total speech time along with inspection time task scores. These analyses were conducted for both the walking condition and the standing condition. The following results were found:

Influence of information processing speed on articulation time and pause time in the walking condition. A repeated measure multivariate analysis of covariance (MANCOVA) was conducted to evaluate the influence of information processing speed on men and women's separate durational speech variables (i.e., articulation time and pause time) while walking. "Sex" served as a between group independent variable with 2 levels (male, female) and "lexicality" served as a within group independent variable with 2 levels (non-word, real word). Total speech time (a durational measure) served as a dependent variable and was broken down into articulation time and pause time measures. Speed of information processing (i.e., inspection time score) was included as a covariate factor.

Appendix J shows the results of the MANCOVA when the inspection time covariate was included in the analysis. Results from this MANCOVA suggests that, after controlling for inspection time, there were no multivariate effects of lexicality, lexicality interacting with IT scores, or lexicality interacting with sex on articulation time or pause time (See Appendix K). There was also no univariate effect of lexicality on articulation time [F (1, 29) = 3.282, p= 0.080, $\eta^2_{partial}$ = 0.102] (Appendix L). Results from the MANCOVA (Appendix J) indicated that the covariate (IT) did not significantly predict either of the dependent variables; articulation time [F (1, 29) = 0.115, p= 0.737, $\eta^2_{partial}$ = 0.004] or pause time [F (1, 29) = 0.683, p= 0.415, $\eta^2_{partial}$ =

0.023]. Therefore, the articulation time and pause time of real-words and non-words were not influenced by a participant's inspection time score. Of particular interest, however, is that when the potential effects of individual speed of information processing (IT score) was removed, there was a statistically significant effect of sex on participants' pause times [F (1, 29) = 9.091, p = 0.005, $\eta^2_{partial}$ = 0.240] (Appendix J). Therefore, these results suggest that sex was accountable for 24 % of the variability in pause time between men and women.

Influence of information processing speed on total speech time in the walking condition. A repeated measures analysis of covariance (ANCOVA) was conducted to evaluate the influence of speed of information processing on men and women's separate total speech time while walking. "Sex" served as a between group independent variable with 2 levels (male, female), "lexicality" served as a within group independent variable with 2 levels (non-word, real word) and total speech time (a durational measure) served as a dependent variable. Speed of information processing (i.e., inspection time score) was included as a covariate factor.

Appendix M shows the results of an ANCOVA when the inspection time covariate was included. Appendix N shows the multivariate results from this ANCOVA and demonstrates that, after controlling for inspection time, there were no multivariate effects of lexicality, lexicality interacting with IT score, or lexicality interacting with sex on total speech duration. At the univariate level, results indicate that although inspection time was not a significant predictor of total speech time [F (1, 29) = 0.808, p= 0.376, $\eta^2_{partial}$ = 0.027], sex had a significant effect on participants' total duration of speech [F (1, 29) = 7.730, p= 0.009, $\eta^2_{partial}$ = 0.210] (Appendix M). Therefore, 21 % of the variability in total speech time could be accounted for by the sex of the participant.

Influence of speed of information processing on articulation time and pause time in the standing condition. A repeated measure multivariate analysis of covariance (MANCOVA) was conducted to evaluate the influence of information processing speed on men and women's separate speech duration variables (i.e., articulation time and pause time) while standing. "Sex" served as a between group independent variable with 2 levels (male, female) and "lexicality" served as a within group independent variable with 2 levels (non-word, real word). Total speech time (a durational measure) served as a dependent variable and was broken down into articulation time and pause time measures. Speed of information processing (i.e., inspection time score) was included as a covariate factor.

Appendix O shows the results of the MANCOVA when the inspection time covariate was included in the analysis. Results from this MANCOVA suggests that, after controlling for inspection time, there were no multivariate effects of lexicality, lexicality interacting with IT scores, or lexicality interacting with sex on articulation time or pause time (Appendix P). Appendix Q shows that there were no significant univariate effects of lexicality on articulation time [F (1, 29) = 0.467, p=0.500, $\eta^{2}_{partial}$ = 0.016). Estimated marginal means support this finding, indicating that non-words (M=0.42 seconds) and real words (M=0.46 seconds) were repeated at similar durations. Therefore, all participants appeared to spend approximately the same amount of time articulating non-words and real-words while standing. Results from the MANCOVA (Appendix O) indicate that the covariate (IT) did not significantly predict the dependent variables, articulation time [F (1, 29) = 0.616, p= 0.439, $\eta^{2}_{partial}$ = 0.021] or pause time [F (1, 29) = 1.775, p= 0.193, $\eta^{2}_{partial}$ = 0.06]. Therefore, the articulation time and pause time of real-words and non-words were not influenced by a participant's inspection time score. Of particular interest, however, is that when the potential effects of individual processing capacity

(IT score) were removed, the effect of sex significantly influenced participants' pause times [F (1, 29) = 6.781, p = 0.014, $\eta^2_{partial}$ = 0.190]. Therefore, these results suggest that the effect of sex on pause time was statistically significant after controlling for individual speed of information processing. These results also suggest that after controlling for processing speed, sex was accountable for 19 % of the variability in pause time durations between men and women.

Influence of speed of information processing on total speech time in the standing condition. A repeated measures analysis of covariance (ANCOVA) was conducted to evaluate the influence of speed of information processing on men and women's separate total speech time durations while standing. "Sex" served as a between group independent variable with 2 levels (male, female), "lexicality" served as a within group independent variable with 2 levels (non-word, real word) and total speech time (a durational measure) served as a dependent variable. Speed of information processing (i.e., inspection time score) was included as a covariate factor.

Appendix R displays the results of an ANCOVA when the inspection time covariate was included. Results from this ANCOVA indicate that, after controlling for inspection time, there were no multivariate effects of lexicality, lexicality interacting with IT score, or lexicality interacting with sex on total duration of speech. At the univariate level, results indicate that inspection time was not a significant predictor of total speech time [F (1, 29) =1.841, p= 0.185, $\eta^2_{partial}$ = 0.60] (Appendix R). After controlling for inspection time, sex had a significant effect on participants' total speech time [F (1, 29) = 5.069, p= 0.032, $\eta^2_{partial}$ = 0.149]. Therefore, approximately 15 % of the variability in total duration of speech could be predicted by the sex of the participant.

3.5 Reliability

An intraclass correlational coefficient (ICC) analyses was used to obtain intra-rater and inter-rater estimates of reliability for rate of speech frequency and duration of speech variables combined. The original rater re-measured 10% of data to determine inter-rater reliability and 10% of the data was re-measured by a second individual to determine intra-rater reliability.

The ICC analysis revealed high inter-rater reliability for all measures, with an ICC of 0.992, $p < 0.001$ (Appendix S). The analysis also revealed high intra-rater reliability for all measures, with an ICC of 0.996, $p < 0.001$ (Appendix T). These correlation coefficients demonstrate a very high reliability within and between raters for both frequency and durational rate measurements.

Inter- rater estimates of reliability were calculated for articulation rate, pause rate and total speech rate measures. Table 12 summarizes the descriptive statistics and results of the ICC analyses used to obtain inter-rater estimates of reliability. The values obtained for inter-rater reliability ranged from 0.942 to 0.995. These correlation coefficients demonstrate overall high reliability between ratings for rate of speech frequency measures.

Table 12. Summary of inter-rater estimates of reliability for rate of speech frequency measures

	Rating 1: Mean & SD	Rating 2: Mean & SD	Intraclass Correlation Coefficient
Articulation Rate	1.95 (0.21)	1.94 (0.30)	0.942 *p*=0.000
Pause Rate	1.04 (0.45)	1.10 (0.54)	0.983 *p*=0.000
Total Rate	0.61 (0.14)	0.61 (0.11)	0.995 *p*= 0.000

Note: Standard deviations are shown in parentheses below the means.

Intra- rater estimates of reliability were calculated using ICC for articulation rate, pause rate and total speech rate measures. Table 13 summarizes the descriptive statistics and results of the ICC analyses used to obtain intra-rater estimates of reliability. The values obtained for intra-rater reliability ranged from 0.898 to 0.998. These correlation coefficients demonstrate overall very good reliability between raters for rate of speech frequency measures.

Table 13. Summary of intra-rater estimates of reliability for rate of speech frequency measures

	Rater 1: Mean & SD	Rater 2: Mean & SD	Intraclass Correlation Coefficient
Articulation Rate	2.05 (0.35)	2.04 (0.36)	0.898 *p*=0.000
Pause Rate	1.89 (1.33)	1.94 (1.33)	0.998 *p*=0.000
Total Rate	0.80 (0.25)	0.79 (0.25)	0.993 *p*= 0.000

Note: Standard deviations are shown in parentheses below the means.

Chapter 4

4 Discussion

4.1 Overview

The overall goal of this study was to investigate the dual-task interference effects of walking on rate of speech. In this study, both rate of speech measures (articulation rate, pause rate, total speech rate measured in syllables/second) and speech durational measures (articulation time, pause time, total speech time measured in seconds) were calculated. Including both frequency and duration measures was necessary in order to derive units of measurement that can be interpreted and discussed in a meaningful manner. For example, pause rate is a relatively meaningless value because its unit of measurement is in pauses/second. It is much more meaningful to measure a pause using a durational measure (in seconds). However, it was required that pause rate (syll/sec) be calculated since pause rate is a contributing variable to overall speech rate (i.e., articulation rate + pause rate = overall rate). Therefore, for clarity, the remainder of this discussion will focus on the interpretation of results relating to the most conceptually meaningful units of measurement related to rate of speech: articulation rate (syll/sec), pause time (sec) and total speech rate (syll/sec).

Objective 1: Dual- task effects of walking on rate of speech.

This objective examined the dual-task interference effects of walking versus standing on rate of speech during the production of real-words and non-words. In order to examine rate of speech between walking and standing conditions, a series of paired samples t –tests were conducted that compared average articulation rate (syllables/sec.), pause time (seconds) and total speech rate (syllables/sec.) of participants' production of real-words and non-words in both the standing and walking conditions.

Articulation rate (syllables/second). The results of this analysis revealed no significant difference in the articulation rate of non-words between the walking (*M*=2.64, *SD*=0.60) and the standing conditions (*M*=2.56, *SD*=0.53). In addition, no significant differences were found in the articulation rate of real-words between the walking (*M*=2.40, *SD*=0.53) and the standing conditions (*M*=2.40, *SD*=0.53).

Based on our results and previous literature, it appears that articulation rate is a relatively stable aspect of speech production. This interpretation is consistent with that of Goldman-Eisler (1961) who suggested that the actual articulation movement involved in producing speech sounds has very little range of variation. She suggested that pause time is the largest contributor to any perceived change in total speech rate. Articulation rate is a more stable parameter because its variation may be constrained by social factors such as gender or age (these factors will be discussed in following sections) (Robb et al., 2003). Furthermore, variations are limited by the anatomical and physiological constraints of the organs used for phonation (Tsao & Weismer, 1997). Despite these findings, a study by Miller, Grosjean and Lomanto (1984) argued that measures of articulation rate, particularly in conversational speech, possess considerable variability and should not be overlooked in comparison to pause variations. In the current study, the artificial nature of the speech task (i.e., repetition of a string of verbal stimuli) coupled with the production of very discrete single-syllable and bi-syllabic stimuli, may have accounted for the non-significant results between experimental conditions. Future examination of more ecologically valid speech tasks, such as repetition of sentences or conversational speech are warranted in dual-task studies.

Pause time (seconds). Significant differences were observed in the duration of pause time in both the walking and the standing conditions. More specifically, the results revealed that participants had significantly longer pause durations while standing and producing both real words (*M*=0.68, *SD*=0.35) and non-words (*M*=0.68, *SD*=0.35), but they paused for shorter durations while producing both real words (*M*=0.53, *SD*=0.30) and non-words (*M*=0.53, *SD*=0.30) when walking. These results suggest that pause time has less stability than articulation rate, and that pause time can be differentially affected by a simultaneous gait task.

Pause time is an important variable to examine since it, along with articulation rate, contributes to total rate of speech estimates. Goldman-Eisler (1961) found that pause time has large variability. For instance, speech utterances collected from interviews in her 1961 study, demonstrated that the range of variation between pause time and total speech time was roughly five times more than the amount of variation in articulation rate (Goldman-Eisler, 1961). Examining the variability of pause time and its contribution to overall speech rate is necessary in order to explore the significant differences in pause durations between the walking and standing experimental conditions.

The manipulation of pause time is often used as a form of rate control in dysarthric populations (Turner & Weismer, 1995; Tjaden & Wilding, 2010).These researchers believe that pausing for a longer period of time or pausing more frequently can help individuals who have various neurologic diagnoses capitalize on their speaking strengths (Tjaden & Wilding, 2010). There are other reasons that may cause pause time to fluctuate. For example, individual speaker characteristics, the emotional state of the speaker, and the situation in which the speaker is speaking may influence pause time durations (Robb et al., 2003).

In the current study, results demonstrated that participants paused significantly less when walking and articulating than when standing and articulating. This finding may reflect motor entrainment of speech (Port, 2003). Previous studies of speech and language within dual-task paradigms have demonstrated that individuals may synchronize their speech when completing a concurrent task such as finger tapping (Smith et al., 1986; Allen, 1972; 1975; Kemper, Herman & Cindy, 2003). For instance Smith et al. (1986) found that mutual interactions of speaking and tapping existed through methods of entrainment. In their study, subjects performed speaking and tapping tasks at a preferred rate and at different rates (e.g., change in repetition or amplitude of one or both tasks). Results indicated that when participants tapped and talked at their preferred rate, they completed the tasks in coordination. However, entrainment patterns were not shown when the simultaneous tasks were completed at different rates (Smith et al., 1986). Allen (1972, 1975) found similar patterns of motor speech entrainment. He asked English speakers to align their finger tap to a word, and found that participants would typically time their tap to the onset of the vowel in the stressed syllable of the word (Allen, 1972, 1975). Port (2003) says this synchronization suggests a perceptually salient acoustic event at these time points (vowel onsets) in speech. Port (2003) also explains that periodic behaviour may occur because neurocognitive oscillations in the brain produce pulses that are sometimes coupled to external periodicities. These oscillations may align with events across multiple modalities (e.g., speech, limb motion, audition, cyclic attention) to solve problems in complex motor coordination (Port, 2003). Given this explanation, our results may suggest that the simultaneous gait task may have acted as a rhythmic periodic attraction, and therefore prompted participants to entrain their speech to parameters of gait (i.e., stride length, step time). Therefore, an important next step in this research would be to examine potential correlations between different gait parameters and speech rate variables to confirm or refute this hypothesis.

Total speech rate (syllables/second). Significant differences were observed in the total speech rate of non-words and real words between walking and standing conditions. In particular, the results showed that total speech rate was faster in the walking condition [real-words (*M*=1.04 syll/sec, *SD*=0.34), non-words (*M*=1.09 syll/sec, *SD*= 0.35)] than in the standing condition [real-words (*M*=0.91 syll/sec, *SD*=0.34), non-words (*M*=0.92 syll/sec, *SD*= 0.30)]. Therefore, total rate estimates suggest that total rate of speech increased when participants completed a simultaneous gait task.

Although articulation rates were not significantly different between the walking and the standing conditions, significant differences were observed in total speech rate estimates between walking and standing. The significant difference found in total speech rate measures, may be due to the inclusion of pause time in total rate estimates. Any fluctuations in pause length, such as an increase or decrease in duration, will cause a corresponding change to total speech rate. Walker and Archibald (2006) explained that decreased pause times can cause total speech rate to appear faster, while increased pause times can cause total speech rates to appear slower. The significant difference in total speech rate between walking and standing appears to be supported by the work of Kemper et al., (2003).

In 2003, Kemper and colleagues conducted a series of dual-task manipulations (e.g., simultaneously talking while walking, finger tapping, or ignoring external noise) to investigate the influence of concurrent tasks on the speech of young adults (aged 18- 28) and older adults (aged 70 -80). Participants were required to describe an event while performing one of the three concurrent tasks. The recorded speech samples were evaluated on verbal fluency, grammatical complexity and content. The results of Kemper et al.'s study suggested that both groups were able to meet the dual-task demands of each concurrent pairing. However, the young adult cohort responded to dual –task demands differently than the older adult group. Of particular interest to the current study are the results pertaining to the concurrent walking and talking task. Based on words per minute estimates, older adults were more likely to slow their total rate of speech while walking (e.g., dual-tasking) than while standing. In comparison, younger adults continued to speak at similar rates when standing and walking, however, data showed that they typically reduced their sentence length and grammatical complexity while walking and producing speech. The results of Kemper's study found that both groups maintained the content of their speech, but adapted to dual-task demands by reducing rate of speech or grammatical complexity. Based on the results from the younger adults in the study by Kemper and others, it appears that our results are similar for articulation rates but not for total speech rate. That is, the articulation rate of our participants remained relatively stable between the walking and standing conditions, but total speech rate was significantly faster during the walking condition than during the standing condition. Kemper et al. (2003) suggested that healthy young adults are able to dual- task (e.g., walk and talk) well, but the execution of both tasks requires that speech performance be altered. In our study it is likely that total speech rate was faster during the walking condition than the standing condition due to motor entrainment of walking and speaking. Previous literature suggests that individuals walk approximately at 120 steps per minute (Barreira, Katzmarzyk, Johnson, & Tudor-Locke, 2012). When values are converted to steps per second, results indicate that individuals have an approximate step time of 2 steps per second or 1 step per millisecond. Davie et al. (2011) reported similar step time values, demonstrating that participants produced both monosyllabic and bisyllabic nonwords and real words at an average step time of 0.52

milliseconds. In comparison, participants in the current study had a slower than normal speech rate that fell in the range of 2- 3 syllables per second. Together, step time estimates from previous literature, and the syllable production estimates from the current study, may suggest that participants perhaps entrained their syllable production to their step production in a dual-task paradigm. Therefore, as aforementioned, an important next step in this research would be to examine potential correlations between different gait parameters (i.e., step time, step length, velocity) and speech rate variables to confirm or refute this hypothesis.

Overall, our investigation demonstrates that the importance of examining articulation rate, pause time and overall speech rate in order to derive a clearer sense of what variables are susceptible to change and which variables inherently have more stability. Previous studies have suggested that articulation rate (i.e., number of syllables produced per second, excluding pauses) is a more accurate measurement of speech rate (i.e., speed at which speakers shape and configure their oral cavities to produce speech) than total speech rate (Walker & Archibald, 2006; Crystal & House, 1982; Pellowski, 2010). However, it remains important to examine total speech rate and pause times, since these measures can help ascertain the aspects of speech production that are susceptible to change in different contexts, such as dual-task paradigms. Our results suggest that articulation rate is a relatively stable aspect of speech production in a dual-task paradigm that involves repetition of single words. Our results also suggest that total speech rate can be influenced by a dual- task paradigm involving a speech and gait task. It appears that pause time is the more modifiable aspect of speech production. More specifically, it appears that total rate of speech was significantly slower in the standing condition versus the walking condition because participants paused for longer durations between both real-words and non-words when standing than when walking. Therefore, these results suggest that rate of speech is differentially altered during a simultaneous gait task and our results may be revealing motor entrainment to the gait task.

Objectives 2 and 3: The influence of lexicality and sex on rate of speech variables

The purpose of these objectives was to evaluate the influence of word meaning (i.e., lexicality) and sex on rate of speech variables (i.e., articulation rate, pause time, total speech rate) within a dual-task paradigm.

Lexicality. The results of this study indicated that word meaning had a significant effect on the articulation rate of participants while walking**.** In particular, our results demonstrated that participants articulated non-words (*M* = 2.64, *SD* =0.60) significantly faster than real-words (*M* = 2.40, *SD* = 0.53) when walking. Word meaning did not significantly influence participant's articulation rate in the standing condition. The pause times of participants were not influenced by word meaning in either of the walking or standing conditions. However, participants' total speech rate values were significantly influenced by word meaning while walking**.** This result suggests that participants had a faster total speech rate (in syllables per second) while walking and producing non-words [*M*=1.09, *SD*= 0.35] versus real words [*M* =1.04, *SD* = 0.34]. Participants' total speech rates were not influenced by word meaning in the standing condition.

Based on the articulation rate and total speech rate values, our results suggest that the production of real words, rather than non-words, while walking may have resulted in greater effects of dual-task interference. These results appear to be consistent with previous dual-task (Pashler, 1994; Marslen-Wilson & Tyler, 1980) and lexical processing literature (Baddeley & Hitch, 1974; Jarrold, Hewes, & Baddeley, 2000; Baddeley, 2003). Past studies have suggested that dual-task interference is greater in situations that require a participant's processing capacity to be more taxed (Marslen-Wilson & Tyler, 1980). In the present study, our results suggest that the added complexity of motor movement (i.e., the walking condition), in comparison to the static standing condition, produced greater effects of dual-task interference on both articulation rate and total speech rate during the production of real words. The difference in speech rate values may be interpreted through the work of Baddeley and Hitch (1974) who proposed that both working memory and attention affect how effectively humans speak. During lexical processing, a phonological loop maintains an utterance in working memory during preparation for production (Baddeley & Hitch, 1974; Baddeley, 2003*)*. If an additional task (e.g., gait task) is to be performed while phonological preparation (verbal speech task) is still occurring, it is possible that the concurrent task will affect attention and will interfere with speech production (Pashler, 1994). This explanation would support the capacity sharing model, which assumes that that two attention demanding tasks (e.g., gait and verbal speech task) would require that attention be divided (Pashler,1994).

It is important to note that results of the present study demonstrated that real words had a slower articulation rate than non-words in the walking condition. If dual-task interference is greater in situations that require a participant's processing capacity to be more taxed (Marslen-Wilson & Tyler, 1980), a possible interpretation of our results may be that the production of real-words requires more lexical processing than non-words. Marslen–Wilson and Tyler (1980) explained that information in the mental lexicon is stored within neural structures of the brain that are easily activated by "familiar" stimuli. In application of this theory, real-word stimuli would be more familiar to participants. The familiarity of real-words would potentially make these words more readily activated within neural structures. In contrast, non-words are presumably less familiar and less likely to provoke lexical activation. According to Marslen-Wilson and Tyler's theory (1980), lexical activation is more taxing on a person's processing capacity, and therefore may result in increased susceptibility of dual-task interference.

The lexicality effect found in the current study may also be interpreted through the analysis of diphthongs. A diphthong is a gliding vowel that contains two subsequent vowels (Plante & Beeson, 2012). The articulation of a diphthong is an assimilated blend of vowels, and tends to contrast with so-called pure vowels (i.e., steady state vowels, unchanging) (Plante & Beeson, 2013; Gay, 1968). Previous research suggests that the duration of a pure, simple vowel is shorter than the duration of diphthong (Gay, 1968). In the current study, participants articulated real-words slower than non-words in the walking condition. When we analyze the actual verbal stimuli (Table 1) it is evident that real-words possess more diphthongs than non-words. For instance, the real-word bisyllabic stimulus "today" contains the diphthong /eɪ/. This finding suggests that the incorporation of a diphthong into the real-word stimuli may have inadvertently resulted in participants lengthening their vowel durations, and their overall time spent producing real-words in comparison to non-words in the walking condition.

Sex. The results of this study suggest that although articulation rate was not significantly influenced by sex in the walking or standing conditions**,** pause time was significantly different for each condition based on sex. In particular, women, spent significantly less time pausing (in seconds) between non-words (*M* = 0.40, *SD* = 0.19) and real-words (*M*=0.42, *SD*=0.21) than men did between non-words (*M*=0.69, *SD* = 0.34) and real-words (*M* = 0.68, *SD* = 0.34) in the walking condition. Women also spent significantly less time pausing between non-words (*M* = 0.57, *SD* = 0.26) and real-words (*M*=0.56, *SD*=0.26) than men did between non-words (*M*=0.83, *SD* = 0.42) and real-words (*M* = 0.84, *SD* = 0.41) in the standing condition. There was a significant effect of sex on total rate of speech in the walking condition. This result suggests that while walking, women tend to have a total speech rate that is faster than men. Specifically, women produced non-words (*M* = 1.21, *SD* = 0.35) and real-words (*M* =1.16, *SD* = 0.35) more quickly (in syllables per second) than men produced non-words (*M*=0.95, *SD* = 0.29) and real-words (*M* = 0.89, *SD* = 0.26) while walking. Total speech rate was not significantly influenced by sex in the standing condition.

Current research regarding the influence of sex on speech rate is controversial. A number of studies have investigated the influence of sex on articulation rate, including Kowal et al. (1975) and Walker et al., (1992) who both utilized narrative samples in their investigations, and Amster (1984) and Haselager et al. (1991) who investigated the influence of sex in conversational speech samples. Each study examined the speech of developing children. None of these investigations, however, demonstrated significant sex differences in rate of speech.

Venkatagiri (1999) examined the influence of sex on rate of speech in an adult population. The results from this study failed to find any differences between men and women's rate of speech while reading aloud or speaking (Venkatagiri, 1999). Some studies have suggested that men read faster than women when completing reading tasks (Jacewicz et al., 2009) and conversational tasks (Verhoeven et al., 2004). These findings are in contrast to the sex effects demonstrated in the present study. It should be noted that the data from Jacewicz et al. (2009) and Verhoeven et al. (2004) studies were derived from different speech tasks and were not completed within a dual-task setting. In addition, both studies noted that their results should be interpreted with caution. Therefore, these studies provide inconclusive evidence that males speak faster than females, when observed in a task such as reading.

The influence of sex on rate of speech variables in the present study differs from previous studies because our results indicate that sex significantly influenced participant pause times, rather than articulation rates. Flipsen (2002) explained that recognizing the differences in both pause durations and articulation rate, may lead to a richer understanding of speech production processes. The results of the current study suggest that women's total rate of speech was significantly faster than men's regardless of whether they were walking or standing. Sex did not significantly influence the articulation rates of men and women in either condition. However, pause times demonstrated that women produced shorter pause lengths between non-words and real-words than men did between non-words and real-words. Walker and Archibald (2006) explained that fluctuations in the duration of pauses can have a direct influence on total speech rate estimates. Based on the arguments of Walker and Archibald (2006), the results of the present study suggest that sex influenced total speech rate estimates due to the inclusion of significantly different pause time durations in total speech rate measurements. The difference in pause time between men and women may be interpreted relative to a study by Davie et al. (2011).

In 2011, Davie and her colleagues investigated the influence of a simultaneous oral-motor speech task on different parameters of gait, and found that men and women's walking parameters (i.e., velocity, step time, swing time, and step length) reflected effects of dual-task interference. In particular, women's walking parameters displayed greater amounts of dual-task interference than that of men. These researchers explained that women were most likely employing a posture first strategy, in which they demonstrated a tendency to slow their walking speed and shorten their step length, while completing a concurrent cognitive speech task. The study also noted that women's dual-task interference was greater when the lexical demands of the concurrent speech task increased while walking (e.g., performance of real words rather than non-words, elicited greater effects of dual-task interference on gait parameters).

In contrast, the results of the current study appear to be inversely related to the results of Davie and others. For instance, the current study examined the influence of a simultaneous gait task on different rate of speech variables (i.e., total speech rate, articulation rate and pause time) and found that men's speech rate variables displayed greater amounts of dual-task interference than that of women. In particular, men demonstrated a tendency to slow their total rate of speech and lengthen their pause time while walking and talking which suggests that these speech variables were subject to dual-task interference. Furthermore, men typically experienced greater effects of dual –task interference when the lexical demands of the speech task increased while walking (i.e., performance of real words rather than non-words, elicited greater effects of dual-task interference on total rate of speech and pause time variables).

The results from the current study, interpreted with the findings of Davie et al. (2011) suggest that men and women possibly respond to the demands of concurrent gait and speech tasks differently. For example, when walking and producing speech, dual-task interference in women may be displayed more in gait parameters (i.e., slowed walking speed and shortened step time) than speech production, while in men, dual-task interference may be displayed more in speech production (i.e., slowed total speech rate, and lengthened pause time) than gait performance. Although each study provided differential sex effects of dual-task interference on speech variables and gait parameters, both studies showed that dual-task effects became intensified when the concurrent speech task required the production of real words while walking.

Overall, Objectives 2 and 3 in the current study suggest that results reveal differential effects of lexicality and sex on rate of speech variables. More specifically, results suggest that articulation rates may be primarily influenced by word meaning, while pause times may be primarily influenced by sex.

Objective 4: The influence of speed of information processing and sex on dual-task interference.

The fourth and final objective of this study evaluated the extent to which dual-task interference on rate of speech was due to speed of information processing. To review, the capacity sharing model focuses on demands of attention, assuming that there is one central processing system that is limited (Pashler, 1994). In comparison, the bottleneck (Pashler, 1984; McCann & Johnston, 1992; Pashler, 1994) and cross talk (Navon & Miller 1987; Pashler, 1994) theories only focus on the type of tasks that are being performed. One way to test these theories is to measure an individual's speed of information processing (SIP), which is the rate at which an individual detects and responds to stimuli (Sheppard & Vernon, 2008). In the current study, speed of information processing was measured through the use of an inspection time (IT) task. This type of task supports the capacity sharing model as it assumes that task performance is limited by an individual's cognitive capacity (O'Shea, Morris, & Iansek, 2002). Inspection time procedures measure processing capacity by determining the speed at which a stimulus can appear on a computer screen, before a participant becomes unable to correctly recognize outstanding characteristics (Johnson et al., 2012; Nettelbeck, 1982). Inspection time may therefore, potentially account for the limited capacity of cognitive systems (Johnson et al., 2012). In previous dual-task literature, Davie and colleagues (2011) found inspection time to be a significant predictor of dual-task interference on parameters of gait during the production of a concurrent speech task. The significant results of the Davie's study appeared to support the capacity sharing model (Pashler, 1994), suggesting that dual-task performance (e.g., walking and talking) was limited by an individual’s cognitive capacity (O'Shea, Morris, & Iansek, 2002).

In objectives 2 and 3, results demonstrated that rate of speech variables were influenced by word meaning and sex. In objective 4, based on the previous findings of Davie et al. (2011), it was thought that cognitive processing could perhaps explain the dual-task interference effects of walking on rate of speech. Therefore, inspection time scores were included as a covariate in each analysis to determine if the effects of dual-task interference on rate of speech variables (e.g., articulation rate, pause time, and total speech rate) were due to lexicality and sex, or speed of information processing.

Results of the current study provide evidence that speed of information processing does not appear to predict the effect of dual-task interference on any of the rate of speech variables. For example, results revealed that inspection time did not predict articulation rate in the walking or standing conditions. Instead, data suggested that word meaning influenced articulation rate while walking, but not while standing. More specifically, results suggested that in the walking condition, 12.3 % of the variation in participant’s articulation rate was due to the word meaning of the stimuli.

The removal of inspection time scores also revealed that sex, rather than processing capacity, influenced pause times in both the walking and standing conditions. In particular, results suggested that sex accounted for 24% of the variability in pause times while walking, and 19% of the variability in pause times while standing.

Lastly, results revealed that inspection time, and word meaning, were not significant predictors of total speech rate estimates in the walking and standing conditions. Instead, results demonstrated that only sex influenced total speech rate while walking. More specifically, results suggested that participant gender was accountable for 17.2 % of the variability in total speech rate while walking. Sex did not influence total speech rate in the standing condition.

Overall, these results provide evidence to support the previous findings of objectives 2 and 3 which suggest that when walking, articulation rates appear to be primarily influenced by word meaning, while pause times and total rates of speech appear to be primarily influenced by sex. These results suggest that men and women respond to dual-task demands differently. However, contrary to the findings of Davie et al. (2011), these results do not reference inspection time as a significant predictor of dual-task performance. The performance of each concurrent task (i.e., walking and speech production) was not limited by participant processing speed.

The results of the current study do not appear to support the capacity sharing model, but offer grounds to interpret results through alternative dual-task theories that may be more relevant to dual-task interference effects on speech production. Other dual-task theories to consider such as the cross-talk (Navon & Miller, 1987) and the bottleneck (Pashler, 1984; McCann & Johnston, 1992; Pashler, 1994) theories focus on the type of tasks that are processed. Perhaps the present study would have produced significant/different results if more ecologically valid speech tasks were employed among experimental conditions. The repetition of single-syllable and bi-syllable words may be too artificial in nature. A speech task consisting of sentence repetition rather than single word repetition may elicit different effects. Similarly, the alternative use of a conversational speech task could alter rate of speech parameters and their interaction with inspection time scores. For example, a conversational speech task would enable participants to not only speak at a preferred rate, but also initiate their own spontaneous speech patterns. This type of task would presumably elicit more lexical processing because the task is internally cued. It is suggested from previous studies, such as Smith et al. (1986) that individuals entrain their speech and finger tapping when concurrent tasks are completed at preferred rates. Based on these findings, perhaps a conversational speech task coupled, with a concurrent gait task, may demonstrate stronger evidence of synchronized gait and speech production entrainment since participants not only walk at a preferred rate, but also speak in a preferred way with preferred content. Lastly, in this study we considered rate of speech variables, however, other speech parameters such as speech intensity or speech intelligibility could produce different results.

4.2 Limitations of Current Study

Although the current study yielded some interesting findings, it is important to acknowledge the methodological limitations. The first methodological limitation relates to the sound quality of participants' previously recorded speech trials. A Starkey Soundport Flex Bluetooth headset with flexible boom microphone was used for recording participants' speech. Recordings were made using Quicktime Pro software running on a Dell desktop computer, connected to a CRT display which had been connected via a wireless Bluetooth connection to the headset. Unfortunately, this form of instrumentation produced poor quality audio recordings of the participants' speech samples. Due to the poor audio recording quality, 8 participants were removed. Therefore, the sample size of the current study was decreased from 40 participants to 32 participants (18 females and 14 males).

The second limitation of the present study relates to the frequency range of the Starkey Soundport Flex Bluetooth headset that was used to record participant's speech data. This headset was able to record an audible frequency range between 0 – 4000 Hz. In the current study, many words and non-words were produced at a frequency that was greater than 4000 Hz. Therefore, the systems inability to record higher frequency sounds, may have limited our ability to record true frequencies of speech stimuli. In addition, the sampling rate of the recorded audio signal is unknown.

The third limitation of the present study relates to the composition of the participant groups. The first of these limitations is the relatively small sample size of 32 participants. An increased number of participants would have increased the statistical power of the study. The second of these limitations is related to the unequal number of male and female participants studied. Since sex was a variable of interest, an unequal number of men and women may have influenced the results.

The fourth limitation of the present study is a methodological limitation relating to the measurement of pause time. A pause or a silent interval was measured as the duration of time that existed from the offset of one Articulatory Run to the onset of the next Articulatory Run. For example, if the assigned stimulus was "today", then the "offset" was recognized as the pulse of the vowel */eɪ/* in "today", whereas the "onset" was identified as the release of the oral stop /t/ in the following Articulatory Run. In previous literature the duration of a pause is defined as a disruption of verbal output that lasts more than 200 msec (Grosjean & Collins, 1979). However, this 200 msec criterion is often criticized for its lack of clarity (Tsao & Weismer, 1997). For example, the literature states that a typical stop closure interval lasts anywhere from 70 to 100 msec (Stathopolous & Weismer, 1983). In order to clarify boundaries between a stop closure interval and a pause, the current study defined a pause as a disruption of verbal output that lasts at least 150 msec or more (Tsao & Weismer, 1997). In our data set, there were instances where participants paused less than 150 msec but these "pauses" could not be considered a stop closure interval. Therefore, durations lasting less than 150 msec that were not identified as stop closure intervals were defined as "silent intervals". It should be noted that these "silent intervals" lasting less than 150 msec were included in the calculation of pause time and pause duration (comprising approximately 5% of the data) and as such, may have influenced the results.

Another important methodological limitation of the present study relates to the task utilized. Each participant was required to repeat verbal stimuli during a standing and a walking condition. These verbal stimuli were discrete monosyllabic or bisyllabic units of speech that included both real-words and non-words. Therefore, the artificial nature of the stimuli and the task limit the generalizability of the results to longer, more complex, spontaneous utterances or speech tasks. We also suggest that this type of task may have caused participants to speak slower than normal speech rates (syllables/second) recorded in the speech rate literature. Perhaps the present study would have produced different results if more ecologically valid speech tasks were employed among experimental conditions. For instance, a speech task consisting of sentence repetition rather than single word repetition may have elicited faster/different rate of speech effects. Similarly, the alternative use of a conversational speech task could alter rate of speech parameters.

Lastly, speech measures were limited to patient's habitual rate of speech. During data collection by Johnson et al. (2012), participants were required to repeat a verbal stimulus while walking or standing still. Participants were not given any instructions to modulate their rate of speech and they were not instructed to speak at a faster or slower rate than their habitual rate of speech. Therefore, based on the results of this study, we cannot draw any conclusions or inferences on what “better” speech performance is based on the rate of speech and between males and females or between standing and walking. Results can only speculate that participants were perhaps experiencing signs of motor entrainment and potentially synchronizing their pause time or articulation rate to their step time.

4.3 Future Directions

The results of this study provide preliminary information from which further studies can be developed. Further exploration in this area can be pursued by replicating the current study, and adapting the research design, to investigate the identified key findings at a greater depth.

It would be interesting to replicate this study with older, healthy adults in order to compare performance to younger, healthy adults. This information would add to our limited understanding of how speech rate and inspection time are affected while walking. It would also be interesting to replicate this study using different speech rates such as faster (e.g., 2x faster) or slower rate (e.g., 2x slower) than habitual speech rate. Manipulating speech rate would be an interesting comparison because it may continue to help us understand the differences in articulatory performance and processing capacity between the sexes while dual-tasking.

The current study sought to examine the dual- task effects of walking on rate of speech. An interesting future comparison could incorporate collected gait data, alongside speech data, to compare and determine whether participant step time is correlated with their pause time, for example. If results suggest that step time, stride length, or gait velocity are synchronized or entrained to pause time in a healthy population, further research could investigate the application of speech motor entrainment in at risk populations such as individuals with Parkinson’s disease (PD). Previous literature has investigated the effects of rhythmic auditory-motor stimulation (RAS) on gait velocity in patients with idiopathic PD (McIntosh et al., 1997). Results from this study found significant improvements in the mean gait, velocity, cadence, and stride length of PD patients when they were stimulated with faster RAS. These results suggest that motor entrainment mechanisms do exist in PD populations, despite evidence of basal ganglia dysfunction. These findings have been influential in the study of gait; however, future studies could incorporate the effects of RAS on speech. For example, if healthy individuals naturally entrain their rate of speech to their gait (e.g., stride length), a comparison study may give insight into to whether or not individuals with PD entrain their speech to gait. In addition, individuals with PD may present with problems affecting their rate of speech due to underlying speech impairments. It would be interesting to investigate motor entrainment involving speech and gait in a neurological population where both gait and speech can be affected. If through future studies it was determined that individual’s entrain their articulation time or pause time to their step time, it could be useful to acknowledge and implement these findings in everyday clinical settings. For example, previous studies such as Davie et al. (2011), suggest that the demands of a concurrent oral-motor speech task result in poorer gait performance and therefore place individuals who have impaired gait (e.g., individual’s with Parkinson’s disease) at a greater risk of falling. Through the continued and systematic exploration of speech/gait motor entrainment in PD, future studies may explore novel interventions that use principles of speech motor entrainment. This may inform treatment protocols that seek to improve speech performance or decrease falls in this population. For instance, further research may determine an appropriate level of complexity for a concurrent speech task (e.g., a speech task that is cognitively, motorically and lexically balanced in order to ensure safe completion while walking). Finally, based on the sex differences examined in the current study, future research could seek to understand the factors that contribute to falls and recognize how factors may differ between men and women in the PD population.

4.4 Research and Clinical Implications

The results of this study provide preliminary data on how the speech rate and inspection time of healthy, young healthy adults is affected in a dual task paradigm. Understanding how speech rate and speed of information processing is affected while walking and standing in a healthy young participant group is essential since these individuals can provide a baseline for presumably optimal speech and cognitive performance. With continued systematic study in this area of research, future studies may inform novel assessment treatment protocols for neurologically impaired populations (e.g., PD) that can experience intensified dual-task interference due to the disease process.

4.5 Summary and Conclusions

This study was designed to evaluate the dual task effects of walking on rate of speech by measuring elements of total speech rate, including pause time and articulation rate. The influence of word meaning and sex on rate of speech was also examined. In addition to this research, an inspection time task was used to determine whether speed of information processing, the rate at which an individual cognitively decodes incoming messages, predicts the degree of dual-task interference of walking on rate of speech.

The first objective of this study revealed that rate of speech variables were influenced by dual-task interference effects due to the performance of a simultaneous gait task. Although there was no significant difference found in the articulation rate of non-words or real-words between walking and standing conditions, results suggest that the production of stimuli while walking had an effect on participant’s pause rate and pause time. For instance, frequency measures of pause rate suggest that walking caused participants to increase the number of pauses they produced per second between both non-words and real words. Similarly, durational measures of pause time suggest that participants spent more time pausing between speech stimuli when standing than while walking.

The second and third objectives in this study revealed differential effects of sex and lexicality on rate of speech variables. For example, pause times suggested a sex effect, demonstrating that while walking, women spent significantly less time pausing between speech stimuli than men. Articulation rates suggested a lexical effect, demonstrating an increase in dual-task interference when participants repeated real words rather than non-words while walking.

The fourth objective in this study revealed that speed of information processing did not predict the degree of dual-task interference of walking on rate of speech. Individuals who possessed a faster processing rate did not experience lesser effects of dual task interference on their rate of speech. Given these findings, rate of speech variables appear to be influenced by factors other than processing speed. More specifically, results suggest that pause time and total rate of speech estimates appear to be primarily influenced by sex, while articulation rates appear to be more influenced by word meaning.

This study has revealed relevant and interesting information that can serve as a basis on which to define further studies that investigate our knowledge of rate of speech within a dual-task paradigm. With continued and further exploration, this information has the potential to increase our knowledge of normal speech production as well as to increase our knowledge of performance of concurrent tasks. In addition, the findings from this study will add to a small but growing body of literature regarding men and women's speech patterns in a dual-task paradigm.

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Appendix A

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	AR	12.501	1	12.501	20.350	.000	.412
	PR	13.049	1	13.049	1.784	.192	.058
IT	AR	.460	1	.460	.749	.394	.025
	PR	.915	1	.915	.125	.726	.004
Sex	AR	.910	1	.910	1.481	.233	.049
	PR	46.396	1	46.396	6.342	.018	.179
Error	AR	17.815	29	.614			
	PR	212.144	29	7.315			

Articulation rate is noted as AR. Pause Rate is noted as PR.

Appendix B

Multivariate[a,b]

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
LEXICALITY	Pillai's Trace	.130	2.086[c]	2.000	28.000	.143	.130
	Wilks' Lambda	.870	2.086[c]	2.000	28.000	.143	.130
	Hotelling's Trace	.149	2.086[c]	2.000	28.000	.143	.130
	Roy's Largest Root	.149	2.086[c]	2.000	28.000	.143	.130
LEXICALITY * IT	Pillai's Trace	.028	.398[c]	2.000	28.000	.676	.028
	Wilks' Lambda	.972	.398[c]	2.000	28.000	.676	.028
	Hotelling's Trace	.028	.398[c]	2.000	28.000	.676	.028
	Roy's Largest Root	.028	.398[c]	2.000	28.000	.676	.028
LEXICALITY * Sex	Pillai's Trace	.051	.752[c]	2.000	28.000	.481	.051
	Wilks' Lambda	.949	.752[c]	2.000	28.000	.481	.051
	Hotelling's Trace	.054	.752[c]	2.000	28.000	.481	.051
	Roy's Largest Root	.054	.752[c]	2.000	28.000	.481	.051

a. Design: Intercept + IT_Score + Sex
Within Subjects Design: LEXICALITY

b. Tests are based on averaged variables.

c. Exact statistic

Appendix C

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
LEXICALITY	AR	Sphericity Assumed	.138	1	.138	4.050	.054	.123
		Greenhouse-Geisser	.138	1.000	.138	4.050	.054	.123
		Huynh-Feldt	.138	1.000	.138	4.050	.054	.123
		Lower-bound	.138	1.000	.138	4.050	.054	.123
	PR	Sphericity Assumed	.043	1	.043	.137	.714	.005
		Greenhouse-Geisser	.043	1.000	.043	.137	.714	.005
		Huynh-Feldt	.043	1.000	.043	.137	.714	.005
		Lower-bound	.043	1.000	.043	.137	.714	.005
LEXICALITY * IT	AR	Sphericity Assumed	.027	1	.027	.784	.383	.026
		Greenhouse-Geisser	.027	1.000	.027	.784	.383	.026
		Huynh-Feldt	.027	1.000	.027	.784	.383	.026
		Lower-bound	.027	1.000	.027	.784	.383	.026
	PR	Sphericity Assumed	.011	1	.011	.035	.852	.001
		Greenhouse-Geisser	.011	1.000	.011	.035	.852	.001
		Huynh-Feldt	.011	1.000	.011	.035	.852	.001

		Lower-bound	.011	1.000	.011	.035	.852	.001
LEXICALITY * Sex	AR	Sphericity Assumed	.048	1	.048	1.422	.243	.047
		Greenhouse-Geisser	.048	1.000	.048	1.422	.243	.047
		Huynh-Feldt	.048	1.000	.048	1.422	.243	.047
		Lower-bound	.048	1.000	.048	1.422	.243	.047
	PR	Sphericity Assumed	.009	1	.009	.027	.870	.001
		Greenhouse-Geisser	.009	1.000	.009	.027	.870	.001
		Huynh-Feldt	.009	1.000	.009	.027	.870	.001
		Lower-bound	.009	1.000	.009	.027	.870	.001
Error(LEXICALITY)	AR	Sphericity Assumed	.985	29	.034			
		Greenhouse-Geisser	.985	29.000	.034			
		Huynh-Feldt	.985	29.000	.034			
		Lower-bound	.985	29.000	.034			
	PR	Sphericity Assumed	9.213	29	.318			
		Greenhouse-Geisser	9.213	29.000	.318			
		Huynh-Feldt	9.213	29.000	.318			
		Lower-bound	9.213	29.000	.318			

APPENDIX D

Tests of Between-Subjects Effects

Measure: Total Rate (TR)
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	2.041	1	2.041	9.899	.004	.254
IT	.114	1	.114	.551	.464	.019
Sex	1.240	1	1.240	6.015	.020	.172
Error	5.979	29	.206			

Appendix E

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
LEXICALITY	Pillai's Trace	.075	2.350[b]	1.000	29.000	.136	.075
	Wilks' Lambda	.925	2.350[b]	1.000	29.000	.136	.075
	Hotelling's Trace	.081	2.350[b]	1.000	29.000	.136	.075
	Roy's Largest Root	.081	2.350[b]	1.000	29.000	.136	.075
LEXICALITY * IT	Pillai's Trace	.026	.782[b]	1.000	29.000	.384	.026
	Wilks' Lambda	.974	.782[b]	1.000	29.000	.384	.026
	Hotelling's Trace	.027	.782[b]	1.000	29.000	.384	.026
	Roy's Largest Root	.027	.782[b]	1.000	29.000	.384	.026
LEXICALITY * Sex	Pillai's Trace	.008	.225[b]	1.000	29.000	.639	.008
	Wilks' Lambda	.992	.225[b]	1.000	29.000	.639	.008
	Hotelling's Trace	.008	.225[b]	1.000	29.000	.639	.008
	Roy's Largest Root	.008	.225[b]	1.000	29.000	.639	.008

a. Design: Intercept + IT_Score + Sex

Within Subjects Design: LEXICALITY

b. Exact statistic

Appendix F

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	AR	12.409	1	12.409	24.085	.000	.454
	PR	2.311	1	2.311	.447	.509	.015
IT	AR	.488	1	.488	.946	.339	.032
	PR	4.014	1	4.014	.776	.386	.026
Sex	AR	.031	1	.031	.061	.807	.002
	PR	24.171	1	24.171	4.673	.039	.139
Error	AR	14.942	29	.515			
	PR	149.998	29	5.172			

Appendix G

Multivariate[a,b]

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
LEXICALITY	Pillai's Trace	.045	.662[c]	2.000	28.000	.524	.045
	Wilks' Lambda	.955	.662[c]	2.000	28.000	.524	.045
	Hotelling's Trace	.047	.662[c]	2.000	28.000	.524	.045
	Roy's Largest Root	.047	.662[c]	2.000	28.000	.524	.045
LEXICALITY * IT	Pillai's Trace	.020	.289[c]	2.000	28.000	.751	.020
	Wilks' Lambda	.980	.289[c]	2.000	28.000	.751	.020
	Hotelling's Trace	.021	.289[c]	2.000	28.000	.751	.020
	Roy's Largest Root	.021	.289[c]	2.000	28.000	.751	.020
LEXICALITY * Sex	Pillai's Trace	.047	.686[c]	2.000	28.000	.512	.047
	Wilks' Lambda	.953	.686[c]	2.000	28.000	.512	.047
	Hotelling's Trace	.049	.686[c]	2.000	28.000	.512	.047
	Roy's Largest Root	.049	.686[c]	2.000	28.000	.512	.047

a. Design: Intercept + IT_Score + Sex
Within Subjects Design: LEXICALITY

b. Tests are based on averaged variables.

c. Exact statistic

Appendix H

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
LEXICALITY	AR	Sphericity Assumed	.069	1	.069	.716	.404	.024
		Greenhouse-Geisser	.069	1.000	.069	.716	.404	.024
		Huynh-Feldt	.069	1.000	.069	.716	.404	.024
		Lower-bound	.069	1.000	.069	.716	.404	.024
	PR	Sphericity Assumed	.088	1	.088	.511	.480	.017
		Greenhouse-Geisser	.088	1.000	.088	.511	.480	.017
		Huynh-Feldt	.088	1.000	.088	.511	.480	.017
		Lower-bound	.088	1.000	.088	.511	.480	.017
LEXICALITY * IT	AR	Sphericity Assumed	.035	1	.035	.366	.550	.012
		Greenhouse-Geisser	.035	1.000	.035	.366	.550	.012
		Huynh-Feldt	.035	1.000	.035	.366	.550	.012
		Lower-bound	.035	1.000	.035	.366	.550	.012
	PR	Sphericity Assumed	.030	1	.030	.173	.681	.006
		Greenhouse-Geisser	.030	1.000	.030	.173	.681	.006
		Huynh-Feldt	.030	1.000	.030	.173	.681	.006
		Lower-bound	.030	1.000	.030	.173	.681	.006
LEXICALITY * Sex	AR	Sphericity Assumed	.006	1	.006	.066	.799	.002
		Greenhouse-Geisser	.006	1.000	.006	.066	.799	.002
		Huynh-Feldt	.006	1.000	.006	.066	.799	.002
		Lower-bound	.006	1.000	.006	.066	.799	.002
	PR	Sphericity Assumed	.242	1	.242	1.404	.246	.046
		Greenhouse-Geisser	.242	1.000	.242	1.404	.246	.046
		Huynh-Feldt	.242	1.000	.242	1.404	.246	.046
		Lower-bound	.242	1.000	.242	1.404	.246	.046
Error(LEXICALITY)	AR	Sphericity Assumed	2.800	29	.097			

		Greenhouse-Geisser	2.800	29.000	.097			
		Huynh-Feldt	2.800	29.000	.097			
		Lower-bound	2.800	29.000	.097			
	PR	Sphericity Assumed	5.004	29	.173			
		Greenhouse-Geisser	5.004	29.000	.173			
		Huynh-Feldt	5.004	29.000	.173			
		Lower-bound	5.004	29.000	.173			

Appendix I

Tests of Between-Subjects Effects

Measure: Total Rate (TR)
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1.203	1	1.203	6.312	.018	.179
IT	.184	1	.184	.967	.334	.032
Sex	.690	1	.690	3.618	.067	.111
Error	5.527	29	.191			

Appendix J

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	AT	.580	1	.580	36.021	.000	.554
	PT	1.497	1	1.497	10.543	.003	.267
IT	AT	.002	1	.002	.115	.737	.004
	PT	.097	1	.097	.683	.415	.023
Sex	AT	.029	1	.029	1.793	.191	.058
	PT	1.291	1	1.291	9.091	.005	.239
Error	AT	.467	29	.016			
	PT	4.117	29	.142			

Appendix K

Multivariate^{a,b}

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
LEXICALITY	Pillai's Trace	.106	1.662^{c}	2.000	28.000	.208	.106
	Wilks' Lambda	.894	1.662^{c}	2.000	28.000	.208	.106
	Hotelling's Trace	.119	1.662^{c}	2.000	28.000	.208	.106
	Roy's Largest Root	.119	1.662^{c}	2.000	28.000	.208	.106
LEXICALITY * IT	Pillai's Trace	.017	.249^{c}	2.000	28.000	.781	.017
	Wilks' Lambda	.983	.249^{c}	2.000	28.000	.781	.017
	Hotelling's Trace	.018	.249^{c}	2.000	28.000	.781	.017
	Roy's Largest Root	.018	.249^{c}	2.000	28.000	.781	.017
LEXICALITY * Sex	Pillai's Trace	.048	.712^{c}	2.000	28.000	.499	.048
	Wilks' Lambda	.952	.712^{c}	2.000	28.000	.499	.048
	Hotelling's Trace	.051	.712^{c}	2.000	28.000	.499	.048
	Roy's Largest Root	.051	.712^{c}	2.000	28.000	.499	.048

a. Design: Intercept + IT_Score + Sex

Within Subjects Design: LEXICALITY

b. Tests are based on averaged variables.

c. Exact statistic

Appendix L

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
LEXICALITY	AT	Sphericity Assumed	.002	1	.002	3.282	.080	.102
		Greenhouse-Geisser	.002	1.000	.002	3.282	.080	.102
		Huynh-Feldt	.002	1.000	.002	3.282	.080	.102
		Lower-bound	.002	1.000	.002	3.282	.080	.102
	PT	Sphericity Assumed	2.834E-005	1	2.834E-005	.004	.950	.000
		Greenhouse-Geisser	2.834E-005	1.000	2.834E-005	.004	.950	.000
		Huynh-Feldt	2.834E-005	1.000	2.834E-005	.004	.950	.000
		Lower-bound	2.834E-005	1.000	2.834E-005	.004	.950	.000
LEXICALITY * IT	AT	Sphericity Assumed	.000	1	.000	.501	.485	.017
		Greenhouse-Geisser	.000	1.000	.000	.501	.485	.017
		Huynh-Feldt	.000	1.000	.000	.501	.485	.017
		Lower-bound	.000	1.000	.000	.501	.485	.017
	PT	Sphericity Assumed	2.705E-005	1	2.705E-005	.004	.951	.000
		Greenhouse-Geisser	2.705E-005	1.000	2.705E-005	.004	.951	.000

		Huynh-Feldt	2.705E-005	1.000	2.705E-005	.004	.951	.000
		Lower-bound	2.705E-005	1.000	2.705E-005	.004	.951	.000
LEXICALITY * Sex	AT	Sphericity Assumed	.001	1	.001	1.338	.257	.044
		Greenhouse-Geisser	.001	1.000	.001	1.338	.257	.044
		Huynh-Feldt	.001	1.000	.001	1.338	.257	.044
		Lower-bound	.001	1.000	.001	1.338	.257	.044
	PT	Sphericity Assumed	.003	1	.003	.420	.522	.014
		Greenhouse-Geisser	.003	1.000	.003	.420	.522	.014
		Huynh-Feldt	.003	1.000	.003	.420	.522	.014
		Lower-bound	.003	1.000	.003	.420	.522	.014
Error(LEXICALITY)	AT	Sphericity Assumed	.016	29	.001			
		Greenhouse-Geisser	.016	29.000	.001			
		Huynh-Feldt	.016	29.000	.001			
		Lower-bound	.016	29.000	.001			
	PT	Sphericity Assumed	.202	29	.007			
		Greenhouse-Geisser	.202	29.000	.007			
		Huynh-Feldt	.202	29.000	.007			
		Lower-bound	.202	29.000	.007			

Appendix M

Tests of Between-Subjects Effects

Measure: TT

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	5.739	1	5.739	23.552	.000	.448
IT	.197	1	.197	.808	.376	.027
Sex	1.884	1	1.884	7.730	.009	.210
Error	7.067	29	.244			

Appendix N

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
LEXICALITY	Pillai's Trace	.050	1.520[b]	1.000	29.000	.228	.050
	Wilks' Lambda	.950	1.520[b]	1.000	29.000	.228	.050
	Hotelling's Trace	.052	1.520[b]	1.000	29.000	.228	.050
	Roy's Largest Root	.052	1.520[b]	1.000	29.000	.228	.050
LEXICALITY * IT	Pillai's Trace	.010	.291[b]	1.000	29.000	.593	.010
	Wilks' Lambda	.990	.291[b]	1.000	29.000	.593	.010
	Hotelling's Trace	.010	.291[b]	1.000	29.000	.593	.010
	Roy's Largest Root	.010	.291[b]	1.000	29.000	.593	.010
LEXICALITY * Sex	Pillai's Trace	.003	.076[b]	1.000	29.000	.785	.003
	Wilks' Lambda	.997	.076[b]	1.000	29.000	.785	.003
	Hotelling's Trace	.003	.076[b]	1.000	29.000	.785	.003
	Roy's Largest Root	.003	.076[b]	1.000	29.000	.785	.003

a. Design: Intercept + IT_Score + Sex

Within Subjects Design: LEXICALITY

b. Exact statistic

Appendix O

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	AT	.647	1	.647	48.917	.000	.628
	PT	3.138	1	3.138	14.810	.001	.338
IT	AT	.008	1	.008	.616	.439	.021
	PT	.376	1	.376	1.775	.193	.058
Sex	AT	.007	1	.007	.534	.471	.018
	PT	1.437	1	1.437	6.781	.014	.190
Error	AT	.383	29	.013			
	PT	6.144	29	.212			

Appendix P

Multivariate[a,b]

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
LEXICALITY	Pillai's Trace	.016	.228[c]	2.000	28.000	.798	.016
	Wilks' Lambda	.984	.228[c]	2.000	28.000	.798	.016
	Hotelling's Trace	.016	.228[c]	2.000	28.000	.798	.016
	Roy's Largest Root	.016	.228[c]	2.000	28.000	.798	.016
LEXICALITY * IT	Pillai's Trace	.006	.079[c]	2.000	28.000	.925	.006
	Wilks' Lambda	.994	.079[c]	2.000	28.000	.925	.006
	Hotelling's Trace	.006	.079[c]	2.000	28.000	.925	.006
	Roy's Largest Root	.006	.079[c]	2.000	28.000	.925	.006
LEXICALITY * Sex	Pillai's Trace	.018	.254[c]	2.000	28.000	.777	.018
	Wilks' Lambda	.982	.254[c]	2.000	28.000	.777	.018
	Hotelling's Trace	.018	.254[c]	2.000	28.000	.777	.018
	Roy's Largest Root	.018	.254[c]	2.000	28.000	.777	.018

a. Design: Intercept + IT_Score + Sex

Within Subjects Design: LEXICALITY

b. Tests are based on averaged variables.

c. Exact statistic

Appendix Q

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
LEXICALITY	AT	Sphericity Assumed	.001	1	.001	.467	.500	.016
		Greenhouse-Geisser	.001	1.000	.001	.467	.500	.016
		Huynh-Feldt	.001	1.000	.001	.467	.500	.016
		Lower-bound	.001	1.000	.001	.467	.500	.016
	PT	Sphericity Assumed	4.575E-005	1	4.575E-005	.023	.880	.001
		Greenhouse-Geisser	4.575E-005	1.000	4.575E-005	.023	.880	.001
		Huynh-Feldt	4.575E-005	1.000	4.575E-005	.023	.880	.001
		Lower-bound	4.575E-005	1.000	4.575E-005	.023	.880	.001
LEXICALITY * IT	AT	Sphericity Assumed	.000	1	.000	.153	.698	.005
		Greenhouse-Geisser	.000	1.000	.000	.153	.698	.005
		Huynh-Feldt	.000	1.000	.000	.153	.698	.005
		Lower-bound	.000	1.000	.000	.153	.698	.005
	PT	Sphericity Assumed	4.264E-005	1	4.264E-005	.022	.884	.001
		Greenhouse-Geisser	4.264E-005	1.000	4.264E-005	.022	.884	.001
		Huynh-Feldt	4.264E-005	1.000	4.264E-005	.022	.884	.001
		Lower-bound	4.264E-005	1.000	4.264E-005	.022	.884	.001
LEXICALITY * Sex	AT	Sphericity Assumed	2.449E-005	1	2.449E-005	.022	.884	.001
		Greenhouse-Geisser	2.449E-005	1.000	2.449E-005	.022	.884	.001
		Huynh-Feldt	2.449E-005	1.000	2.449E-005	.022	.884	.001
		Lower-bound	2.449E-005	1.000	2.449E-005	.022	.884	.001

	PT	Sphericity Assumed	.001	1	.001	.472	.498	.016
		Greenhouse-Geisser	.001	1.000	.001	.472	.498	.016
		Huynh-Feldt	.001	1.000	.001	.472	.498	.016
		Lower-bound	.001	1.000	.001	.472	.498	.016
Error(LEXICALITY)	AT	Sphericity Assumed	.033	29	.001			
		Greenhouse-Geisser	.033	29.000	.001			
		Huynh-Feldt	.033	29.000	.001			
		Lower-bound	.033	29.000	.001			
	PT	Sphericity Assumed	.057	29	.002			
		Greenhouse-Geisser	.057	29.000	.002			
		Huynh-Feldt	.057	29.000	.002			
		Lower-bound	.057	29.000	.002			

Appendix R

Tests of Between-Subjects Effects

Measure: Total Speech Time

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	8.792	1	8.792	26.646	.000	.479
IT	.607	1	.607	1.841	.185	.060
Sex	1.672	1	1.672	5.069	.032	.149
Error	9.569	29	.330			

Appendix S

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	72	100.0
	Excluded[a]	0	.0
	Total	72	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.992	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.984[a]	.975	.990	124.475	71	71	.000
Average Measures	.992[c]	.987	.995	124.475	71	71	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Appendix T

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	72	100.0
	Excluded[a]	0	.0
	Total	72	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.996	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.993[a]	.989	.995	273.176	71	71	.000
Average Measures	.996[c]	.994	.998	273.176	71	71	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Curriculum Vitae

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University of Western Ontario
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Related Work Experience

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Interdisciplinary Movement Disorder's Lab (IMDL)
Lab Director: Andrew Johnson, PhD.
Study: *Wood, Kevin. "The effect of articulation and word-meaning on gait and balance in people with Parkinson's disease" (2013).University of Western Ontario - Electronic Thesis & Dissertation Repository.* Paper 1453.
Fall 2012- Spring 2013

Research, Invited lectures, and Symposia Presentations

- [Conference Poster Presentation] **Jablecki, D**., Dykstra, A.D., Domingo, Y., & Jog, M. "Examining levels of speech intelligibility in an individual with Oromandibular dystonia", CALSPO/OSLA Joint Conference 2013: Energized by Excellence, Westin Prince Toronto Hotel, October 16, 2013.

- [Conference Poster Presentation] Domingo, Y**.,** Dykstra, A.D., **Jablecki, D**., Adams, S.G., Johnson, A., & Jog, M. "The effect of measurement technique on speech intelligibility scores in oromandibular dystonia", CALSPO/OSLA Joint Conference 2013: Energized by Excellence, Westin Prince Toronto Hotel, October 16, 2013

- [Speech & Language Science Seminar Presentation] **Jablecki, D**., Dykstra, A.D., Johnson, A.M., Cardy, J., & Holmes, J. "Dual-Task Effects of Walking on Rate of Speech", Western University, London, ON, October 2, 2013.

- [Speech & Language Science Seminar Presentation] **Jablecki, D**., Dykstra, A.D., Johnson, A.M., Cardy, J., & Holmes, J. "Dual-Task Effects of Walking on Rate of Speech", Western University, London, ON, April 3, 2013.

- [Conference Poster Presentation] **Jablecki, D**., Dykstra, A.D., Johnson, A.M., Cardy, J., & Holmes, J. "Dual-Task Effects of Walking on Rate of Speech", FHS Research Day, Western University, London, ON, March 13, 2013.

- [Conference Poster Presentation] Domingo, Y. Dykstra, A.D., **Jablecki, D.**, Adams, S.G., Johnson, A., & Jog, M. "A comparison of speech intelligibility measures obtained from three measurement techniques in Oromandibular dystonia", FHS Research Day, Western University, London, ON, March 13, 2013.

- [Conference Poster Presentation] **Jablecki, D**., Dykstra, A.D., Domingo, Y., & Jog, M. "Examining levels of speech intelligibility in an individual with Oromandibular dystonia", HGRC "Urban Health and Well-being" McMaster University, Hamilton, ON, March 1, 2013.

- [Conference Poster Presentation] **Jablecki, D**., Dykstra, A.D., Johnson, A.M., Cardy, J., & Holmes, J. "Dual-Task Effects of Walking on Rate of Speech", HRS Graduate Research Forum "Sowing Seeds of Ideas for Fruitful Trees", Western University, London, ON, February 6, 2013.

- [Conference Poster Presentation] Domingo, Y. Dykstra, A.D., **Jablecki, D.**, Adams, S.G., Johnson, A., & Jog, M. “A comparison of speech intelligibility measures obtained from three measurement techniques in Oromandibular dystonia”, HRS Graduate Research Forum "Sowing Seeds of Ideas for Fruitful Trees", Western University London, ON, February 6, 2013.

- [Conference Poster Presentation] **Jablecki, D**., Dykstra, A.D., Domingo, Y., Adams, S.G., & Jog, M. "The effect of task on speech intelligibility in Oromandibular dystonia: A case report.", ARGC/FHS SYMPOSIUM “Research to Action: Technology, Innovation & Health”, Western University, London, ON, February 1, 2013.

- [Poster] Domingo, Y. Dykstra, A.D., **Jablecki, D**., Adams, S.G., Johnson, A., & Jog, M. “A comparison of speech intelligibility measures based on three measurement techniques in Oromandibular dystonia” ARGC/FHS SYMPOSIUM “Research to Action: Technology, Innovation & Health”, Western University, London, ON, February 1, 2013.